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MEMOIRS OF THE GEOLOGICAL SURVEY
OF THE
UNITED KINGDOM

THE

CRETACEOUS ROCKS
OF
BRITAIN.

VOL. I.—THE GAULT AND UPPER GREENSAND OF ENGLAND.

BY

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WITH CONTRIBUTIONS BY

WILLIAM HILL, F.G.S.

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PREFACE.

The present volume is the first of two in which the Upper Cretaceous Rocks of England will be described. It deals with that portion of these rocks which includes the strata known as the Gault, Red Chalk, and Upper Greensand. Our presen knowledge of this subject is the outcome of a long series of observations commencing with those of William Smith, who was followed by Thomas Webster, William Phillips, Fitton, Murchison, and Mantell. Of these great workers we are especially indebted to Fitton. In later years the formations received much attention from Godwin-Austen, while their palæontological contents were studied in more detail by Mr. C. J. A. Meyer, Mr. F. G. H. Price, Dr. Charles Barrois, and others.

The mapping of the Upper Greensand and Gault by the Geological Survey on the scale of one inch to a mile has long been finished and published. When a revision of the ground for the purpose of tracing the superficial accumulations on maps on the scale of six inches to a mile was decided upon, advantage was taken of the opportunity to make such revisions of the published maps as time had shown to be desirable. In this way detailed surveys have now been made of the Upper Cretaceous rocks over a large part of the south of England.

In pursuance of the scheme for issuing a series of descriptive monographs of the various rocks of Britain by the Geological Survey, the task of preparing one on the Cretaceous System was entrusted to Mr. Jukes-Browne. It was eventually found needful to divide the labour between two officers of the staff. Mr. Jukes-Browne retained the Upper Cretaceous rocks as his share. He has himself been personally engaged in mapping the rocks and has also devoted much time to the study of the literature attached to them. He has more specially examined various parts of the Cretaceous tract from Lincolnshire and Norfolk to Devonshire, and has revised some of the published maps, in particular inserting the outcrops of the Melbourn Rock and Chalk Rock.

The accumulation of the material for the present Memoir was begun by Mr. Jukes-Browne as far back as the year 1884. But in the earlier years comparatively little time could be spared from other official duties for the actual preparation of the memoir. Eventually his health began to fail and it became no longer possible for him to undertake all the field-journeys that were necessary for completing the information that was required. He was fortunate in finding in his friend Mr. William Hill an able and experienced coadjutor who, thoroughly familiar with the formations, most kindly undertook those journeys and supplied the author with the material which he was no longer able himself

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to gather. He traversed the outcrops of the formations through Kent and Surrey, and also through parts of Hampshire, Sussex, and the Isle of Wight. The Geological Survey is deeply indebted to Mr. Hill for his laborious and helpful assistance.

In the present volume the author has begun his description with a general account of the Upper Cretaceous series and of the flexures to which the present disposition and alignment of the members of that series are due. The history of the names which have been given to the several formations is next narrated, and it is explained that the whole might be grouped under one general designation for which the term Selbornian has been proposed. A short discussion is then given of the value of zones in stratigraphy with special application to those of the Cretaceous Rocks. The three chapters in which these several subjects are treated may be regarded as in some measure introductory to the completed monograph on the Cretaceous System, and not merely to the description of that portion of the system to which the present volume is assigned.

In the fourth chapter a general account is given of the Selbornian Stage as a whole, and of its three groups or sub-stages,—(1) The Lower Gault; (2) The Upper Gault and Devizes Beds; (3) The Warminster Beds. The more important of the fossils found in each of these groups are mentioned and some of them are illustrated by figures.

In arranging the stratigraphical particulars and in describing the exposures of the beds the author has made his chapters as far as possible coincide with the division of the country into counties. These details occupy Chapters V. to XXII. Mr. Hill's contributions to these are chiefly in Chapters V. VI. VII. VIII. and IX., and the account of the Red Chalk of Yorkshire is mainly taken from Mr. Hill's description in the Quarterly Journal of the Geological Society, vol. xliv.

Some information and illustrations have been taken from previously published Memoirs of the Geological Survey, especially those on the Isle of Wight (by A. Strahan), on the Isle of Purbeck (by A. Strahan), those on West Suffolk and West Norfolk (by W. Whitaker and A. J. Jukes-Browne), and that on the neighbourhood of Cambridge (by W. H. Penning and A. J. Jukes-Browne).

In Chapter XXIII. are collected most of the analyses which have been made of Selbornian rocks. They include some not previously published, which have been made by Prof. J. B. Harrison, Mr. R. A. Berry, and Dr. W. Pollard.

Chapters XXIV. and XXV. have been written almost entirely by Mr. Hill and embody researches made by him into the mineral and organic constituents of the deposits, ascertained partly by the washing of samples, partly by examination of residues after treatment with acid, and partly from slides cut for the microscope. During the course of this work Mr. Hill isolated many Foraminifera, and we are indebted to Mr. F. Chapman for examining and naming these, the results thus obtained being embodied in a table on p. 351. In the indentification of the minerals of the residues Mr. Hill received valuable assistance from Mr. J. J. H. Teall.

In Chapter XXVIII. the author has discussed the probable geography of the British area during the Selbornian period, as well as the bathymetrical conditions under which the deposits seem to have been formed.

Economics are dealt with in Chapter XXIX. and Palæontology in the Appendices A and B, the first containing some critical remarks on certain species and the second being a general list of Fossils.

Although Mr. Jukes-Browne is chiefly responsible for the Palæontological portions of this memoir, Mr. G. Sharman and Mr. E. T. Newton have exercised a general supervision, and to them also has fallen the task of rectifying numerous obscure points of synonymy and nomenclature. The specific determination of the fossils collected by the Survey has likewise been carried out by these officers, assisted by Mr. H. A. Allen and Dr. F. L. Kitchin. The fossils obtained by the Survey have for the most part been collected by Mr. J. Rhodes under the superintendence of Mr. Jukes-Browne and Mr. A. Strahan.

In addition to the great services rendered by Mr. Hill the author desires to acknowledge the valuable assistance, as to sections and fossils obtained from them, given to him by Mr. R. M. Brydone, Mr. F. Chapman, Mr. William Cunnington, Dr. W. Curtis of Alton, Dr. G. J. Hinde, F.R.S., and Mr. J. B. Hue of Ventnor.

The second volume in continuation of the present deals with the Chalk and is nearly ready for the printer. Considerable progress has been made in the preparation of the material for the Memoir on the Lower Cretaceous formations.

ARCH GEIKIE,

Director-General.

Geological Survey Office,
28, Jermyn Street, London,
20th March, 1900.

TABLE OF CONTENTS.

CHAPTER V.

CHAPTER VI.

CHAPTER VII.

CHAPTER VIII.

CHAPTER IX.

CHAPTER X.

CHAPTER XI.

CHAPTER XII.

CHAPTER XIII.

CHAPTER XIV.

CHAPTER XV.

CHAPTER XVI.

CHAPTER XVII.

CHAPTER XVIII.

CHAPTER XIX.

CHAPTER XX.

CHAPTER XXI.

CHAPTER XXII.

CHAPTER XXIII.

CHAPTER XXIV.

CHAPTER XXV.

CHAPTER XXVI.

CHAPTER XXVII.

CHAPTER XXVIII.

CHAPTER XXIX.

APPENDIX.

ILLUSTRATIONS.

PLATES.

THE GAULT AND UPPER GREENSAND OF ENGLAND.

CHAPTER I.

INTRODUCTION.

The Upper Cretaceous Series.

The Cretaceous System of England is naturally divisible into two distinct and different series of strata; a lower series consisting of a variable set of sands and clays, with only a few local beds of limestone or calcareous sandstone; and an upper series consisting mainly of chalk, but having at its base a group of greensands, marls, and marly clays.

In this Memoir the upper series only will be dealt with, and this Upper Cretaceous Series will be regarded as consisting of four stages or groups of strata, for which the following names will be used:—

4. Upper Chalk.
3. Middle Chalk.
2. Lower Chalk.
1. Gault and Upper Greensand (Selbornian).

These stages vary greatly in thickness in different parts of the country, but their combined thickness where they are most completely developed is about 1,900 feet. Such is their thickness in the Isle of Wight and probably also beneath the central parts of the Hampshire Basin. In the London Basin the series is incomplete on account of pre-Tertiary and Eocene erosion, and does not exceed 1,000 feet; but in the east of Norfolk the higher beds come in again, and though the lowermost division (Selbornian) is very much thinner than in the south, the whole series is about 1,200 feet thick. Its thickness in Yorkshire, near Bridlington and Flamborough Head, is probably about the same as in Norfolk, the most recent estimate of its thickness by Mr. G. W. Lamplugh being 1,270 feet.

1. The Selbornian comprises the beds which are generally known as the Gault and the Upper Greensand. It is not intended to supersede these names on the maps of the Geological Survey, because on these maps it is always desirable to represent,

as far as possible, by different colours the deposits of different lithological character; moreover, in the description of certain areas, it will still be convenient to speak of the argillaceous and arenaceous portions of the formation as Gault and Upper Greensand. A new name, however, is required for the stage as a whole, to prevent the perpetuation of the error that the Gault and Greensand are separate and independent formations. Further explanation of this matter will be given in the sequel. In the counties of Yorkshire, Lincolnshire, and part of Norfolk, the Selbornian is represented by the rock which is known as the *Red Chalk.*

The name Selbornian has been chosen from the well-known village of Selborne, in Hampshire, where Gilbert White lived and laboured more than a hundred years ago. (*See* p. 30.)

2. The LOWER CHALK comprises the beds which were formerly known as *Chalk Marl* and *Grey Chalk,* as well as a certain thickness of the "white chalk without flints." Over the greater part of England, its basement bed is a sandy glauconitic marl, often containing phosphatic nodules; in certain areas this has been called the Chloritic Marl, in others the Cambridge Greensand; but over the area of the Red Chalk its lowest bed is a pure limestone without any admixture of sand. Its summit is generally defined by a band of grey marl in which the Belemnite *Actinocamax plenus* is frequently to be found.

The total thickness of the Lower Chalk varies from 250 to about 60 feet. In Devon its place is taken by calcareous sandstone and quartziferous limestone, varying from 1 to 40 feet in thickness.

It corresponds with the true (restricted) *Cenomanian* of France.

3. THE MIDDLE CHALK consists partly of hard rocky or nodular chalk and partly of firm white chalk. Its basement-bed is the hard nodular chalk to which the name of Melbourn Rock has been given. Flints are generally absent from the lower part, are sparingly distributed in its middle portion, but are sometimes numerous in the higher beds.

As defined in this Memoir the Middle Chalk does not include the Chalk Rock of the Midland and Eastern counties, but does include the bed to which that name has been applied in Dorset and in the Isle of Wight. Where fully developed, as in the south-eastern counties, the Middle Chalk is about 240 feet in thickness, but in some districts it is not much more than 100 feet.

It corresponds with the *Turonian* stage of French geologists.

4. THE UPPER CHALK is less variable in lithological character than the Middle or Lower divisions; it consists in the lowest part of hard nodular chalk, in which beds of compact limestone frequently occur, one of which is known as the Chalk Rock; the greater part of this division, however, consists of soft white chalk in which flints are generally abundant, but there is a certain zone or portion of it where flints are less common and which is sometimes almost flintless.

Where fully developed the Upper Chalk is more than 1,000 feet thick, but its actual thickness varies greatly in different parts of the country, owing to the great erosion which it suffered at the close of the Cretaceous and during the Eocene period. Thus in the central parts of the London Basin, its thickness has been reduced to between 200 and 300 feet, and though it may never have been 1,000 feet thick in that area, it is probable that several hundred feet of chalk were removed before the formation of the lowest Eocene beds.

It corresponds to the *Senonian* of the French.

Relation of the Upper Cretaceous Series to the Strata below.

The Upper Cretaceous Series as a whole succeeds the Lower Cretaceous Series conformably, but there is evidence that very considerable physical and geographical changes took place at the inception of the upper series. It is true that sometimes there is a passage from the one series to the other, but it is generally rapid, and there is more often a sudden transition from pure sand to sandy clay, and frequently there is a pebble-bed or a layer of phosphatic nodules at the base of the Selbornian.

It is also well known that the upper series overlaps the lower, and spreads far beyond the limits of the latter both in the east and in the west of England. Such a disposition can only have been caused by a general and considerable subsidence of the whole region, whereby the area of the Cretaceous sea was greatly enlarged and that of the surrounding lands was correspondingly decreased. By this subsidence the conditions of sedimentation in the central parts of the sea were rapidly modified, and this is the reason why we find such a change in the nature of the sediment when we pass from the Lower to the Upper Cretaceous Series. Arenaceous deposits were limited to narrow tracts along the retreating shores, and an extensive deposit of mud began to be formed. This mud, now consolidated into clay and marl, is known as the Gault.

The overlap of the Lower Greensand by the Gault toward the east is not visible in England, and we only know that it does take place because deep borings in the east of England have proved that the Lower Cretaceous beds thin out and that the Gault comes eventually to lie directly on the Palæozoic rocks. This subterranean extension of the Gault will be described more fully in the sequel. In the north-east of France, however, some of the littoral deposits formed during this overlap are visible at the surface.

The transgressive extension of the Selbornian in a westerly direction is plainly disclosed in our south-midland and south-western counties. Thus in Wiltshire if we follow the outcrop of the Gault from the opening of the Vale of Pewsey toward Frome, we find it overlapping the Lower Greensand and then passing unconformably across the Portland Beds, the Kimeridge Clay and the Corallian on to the Oxford Clay.

Similarly in South Dorset the Lower Greensand thins out between Mupe Bay and Lulworth Cove, the Gault at the latter place resting directly on the the Wealden Beds; these terminate near Weymouth, and the Gault, hardly distinguishable from the Upper Greensand into which it merges, then passes across the basset surfaces of the several members of the Jurassic Series till it reaches the Rhætic Beds near Axmouth. Continuing the overstep it creeps over the Triassic rocks till finally in the Haldon Hills Greensand rests on the lower part of the New Red Series (Permian), and is within 100 feet of the Palæozoic floor.

As the Selbornian is followed westward the argillaceous portion, or Gault, becomes more and more sandy, and at the same time Cephalopoda become rarer, so that it is difficult to say how far its lower beds (*i.e.* the Lower Gault) continue before they are overlapped by the upper part of the formation. We shall see, however, that there is good reason to believe that the lower beds extend into Devonshire.

General Lie and Position of the Strata.

The area occupied by the Upper Cretaceous series lies mainly in the south and east of England, as will be seen from a glance at the map (Frontispiece). By surface-outcrop and subterranean extension they occupy the greater part of the country which lies to the east of a line drawn from West Dorset to the opening of the Wash. A separate tract occupies parts of Lincolnshire and Yorkshire as far north as the Vale of Pickering, and there are outlying tracts in the east of Devonshire.

The general inclination of the Cretaceous strata is toward the east, but this easterly dip is interrupted by several anticlinal flexures which have an east and west direction and produce local dips to the north and south.

Several of these flexures combine to form the great anticlinal axis of the Weald, which, being continued through Hants and Wilts, separates what is known as the Hampshire Basin from the London Basin. Other flexures of less importance have produced what may be termed the north-eastern basin in Lincolnshire and Yorkshire.

Beyond the limits of English land the Chalk extends eastward beneath the floor of the North Sea, and is doubtless continuous with that of Belgium and Holland. It also extends south-eastward beneath the English Channel into the north of France, where it underlies the whole of the Paris basin.

Principal Lines of Flexure and Disturbance.

In the South of England there are three principal lines of disturbance along which the beds are ridged up into anticlinal flexures, which have a general east and west direction. These are as follows:—

(1.) The strong flexure which traverses South Dorset and the Isle of Wight; this is believed to be continuous with the anticlinal axis of the Pays de Bray in France, which passes through Dieppe and north-east-

ward under the English Channel in the direction of the Isle of Wight.

(2.) A disturbed tract, which is not a continuous line of flexure, but consists of a series of more or less local and parallel flexures, dying out and replacing one another. This tract extends from the Vales of Wardour and Warminster, through central Hants and the southern part of Sussex.

(3.) The anticlinal axis which runs through the Vales of Pewsey and Kingsclere. This is probably continued eastward into the flexure which rolls over northward into the Hog's Back, near Farnham. It dies out near Dorking, or becomes merged in the general uplift of the Wealden area, which is often regarded as an extension of the axis of Artois, in the north-east of France.

It is noticeable that along each line of disturbance the anticlines tend to assume a wave-like form, with a much steeper inclination on the northern than on the southern side. The height and magnitude of the arch and the steepness of its northern slope vary greatly in different localities along the same line of flexure, portions of the anticline often swelling upward into local domes or *bombements*, like that of the Vale of Kingsclere.[1]

The southern line of disturbance is the strongest and probably the most continuous, the strata along its northern border being tilted into a vertical or nearly vertical position, and in Dorset being dislocated by a line of fault, along which much crushing and compression have taken place. Most geologists are familiar with the general features of this flexure as exhibited in the cliffs of the Isle of Wight, but the displacements in Dorset, although pictured by Webster and others, were not fully understood until they were studied and described by Mr. Strahan.[2]

Fig. 1 is reproduced from Mr. Strahan's Memoir, to which the reader is referred for further particulars of the faulting and overthrusts.

The second line of disturbance is a more complex one; it appears to consist of several separate and parallel flexures (anticlinal and synclinal) which die out eastward, and are replaced by another set of similar flexures.

In the west the strongest and most conspicuous flexure of this group is that of the Vale of Wardour. The structure of this district resembles that of the Isle of Purbeck, the beds having a gentle inclination to the south, but a steep pitch to the north, along which border they are cut off by a powerful fault. (See Fig. 67). Notwithstanding the local intensity of this flexure, in which the northerly dips sometimes amount to 50° or 60°, it appears to die out entirely to the south-east of Barford. Another flexure, however, commences to show itself at Berwick St. John, east of Shaftesbury, and is traceable through Bower Chalk and eastward between Salisbury and Downton to East Dean and Dunbridge, where it also dies out. The length of this axis is not more than 24 miles, and its curvature is everywhere slight.

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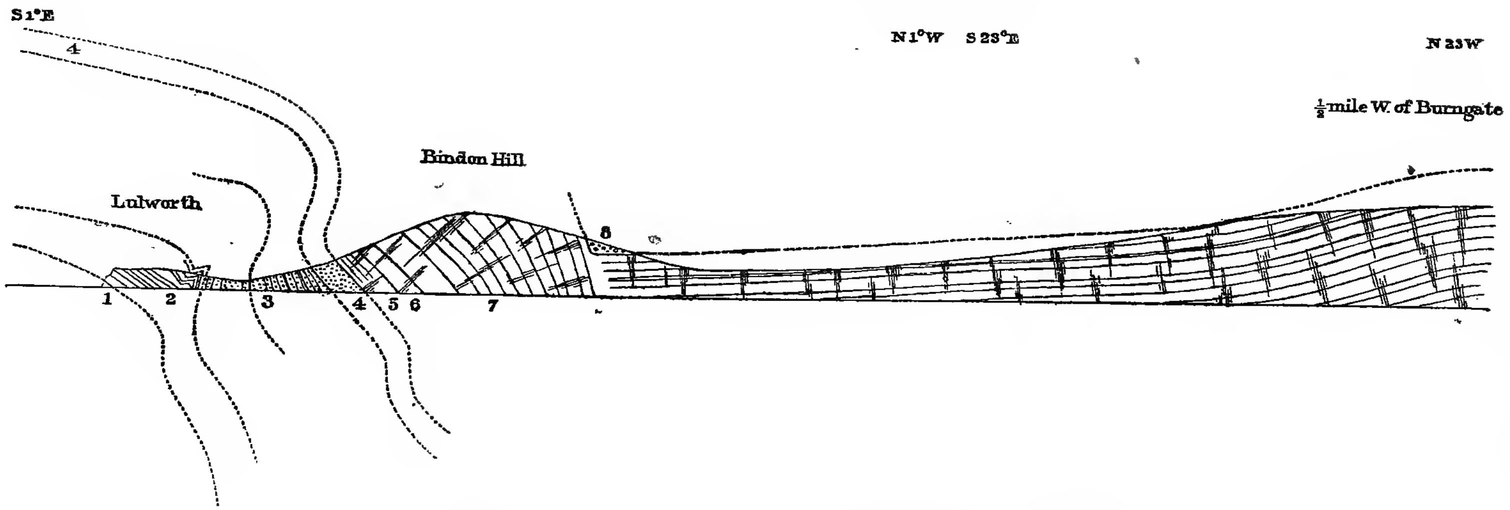
1 See also Hudleston, Proc. Geol. Assoc. vol. vii., p. 179.

2 See Proc. Geol. Assoc., vol. xiv., p. 406 (1896) and "The Geology of the Isle of Purbeck and Weymouth," Mem. Geol. Surv., p. 212 (1898).

Fig. 1. –*Section across the Isle of Purbeck Disturbance near Lulworth.* (A. Strahan.)[1]

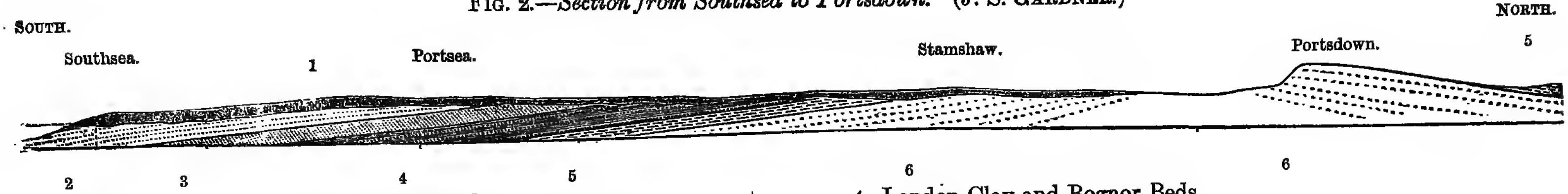


8. Eocene	4. Gault and Upper Greensand.
7. Upper Chalk.	3. Wealden.
6. Middle Chalk.	2. Purbeck Beds.
5. Lower Chalk.	1. Portland Beds.

The Lower Greensand is here cut out by the fault which accompanies the flexure.

[1] Quart. Journ. Geol. Soc., vol. li., pl. xvii.

FIG. 2.—*Section from Southsea to Portsdown.* (J. S. GARDNER.)[1]

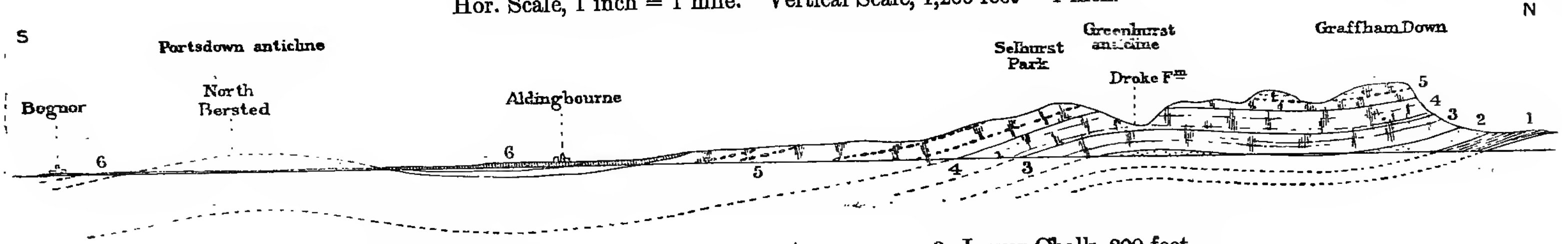


1. Gravel.
2. Bracklesham Beds.
3. Lower Bagshot Beds.
4. London Clay and Bognor Beds.
5. Reading Beds (Mottled Clay).
6. Chalk.

[1] Record of Excursions, Geologists' Association, Fig. 98, p. 297.

FIG. 3.—*Section from Bognor to Graffham Down.*

Hor. Scale, 1 inch = 1 mile. Vertical Scale, 1,200 feet = 1 inch.



6. Eocene.
5. Upper Chalk, 500 feet.
4. Middle Chalk, 200 feet.
3. Lower Chalk, 200 feet.
2. Upper Greensand, 150 feet.
1. Gault, 130 feet.

To the northward a third flexure occurs, also of slight curvature, but traceable for a greater distance. This traverses Longleat and the Vale of Warminster, passes down the valley of the river Wiley to Stapleford, crosses the Avon north of Salisbury, reappears at Winchester, and passes into the Wealden area by East Meon and Petersfield. This has a course of at least 60 miles, and may be regarded as an easterly continuation of the more ancient axis of the Mendip Hills.

Passing into Sussex we find several flexures which certainly form a continuation of the disturbed tract, although they appear to be a distinct and independent set of axes. The most southerly line is the anticline of Portsdown, which runs through Fareham and thence south of Chichester to Littlehampton (see Figs. 2 and 3); it is probably continued still further eastward beneath the sea, and may possibly be the same flexure as that at Treport and the axis of Bresle, in France.

North of this anticline is a syncline which runs through Chichester, Arundel, and Lancing, bringing in a trough of the Lower Eocene Beds. Beyond this comes another anticlinal axis, the western extension of which through the Chalk area was traced by Mr. C. Reid[1] in 1885, and is shown in Fig. 3. This axis coincides with the direction of the valley in which East and West Dean are situated, and emerges from the Chalk Downs near Bignor. The same or a parallel axis, called the Greenhurst anticline by Mr. Topley,[2] brings up a narrow tract of Weald Clay along the valley in which Greenhurst Farm stands. Thence it passes across the Adur, enters the Chalk again near Poynings, and crosses the Ouse south of Lewes, where northerly dips are seen in the Southerham quarries. Thence it ranges through Selmeston, and is probably continued to Pevensey and the coast.

Parallel to this Greenhurst anticline there is a second synclinal trough, which appears to commence in Burton Park south of Petworth, brings in the tongue of Lower Greensand and Gault near Henfield and passes beneath the escarpment of the South Downs at Clayton. It crosses the valley of the Ouse at Lewes, is clearly seen in Mt. Caburn, and is traceable in the outcrops of Gault and Lower Greensand near Rype.

Coming to the third main line of disturbance, we find this forming the Vale of Pewsey in Wiltshire. At its western end near Devizes and as far east as Woodborough the arch of this anticline is very low, and outliers of Chalk occur on the Greensand in the centre of the Vale, but in the eastern part of the Vale the curvature is much stronger, and the dips on the northern side increase to 25° and 30°; those on the southern side, however, do not anywhere exceed an angle of 5°. The Vale ends in a kind of pericline with dips to the south, east, and north-east, but the axis is continued by the Shalbourn inlier, where the Upper Greensand is again brought up to the surface over a small area

[1] Geology of Bognor, Mem. Geol. Surv., p. 1 (1897).
[2] Geology of the Weald, Mem. Geol. Surv., p. 225 (1875).

FIG. 4.—*Section through the Hog's Back at Farnham Park.*

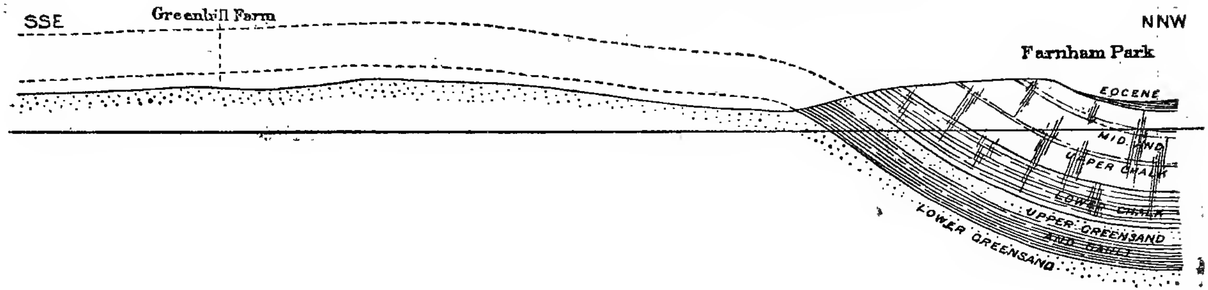
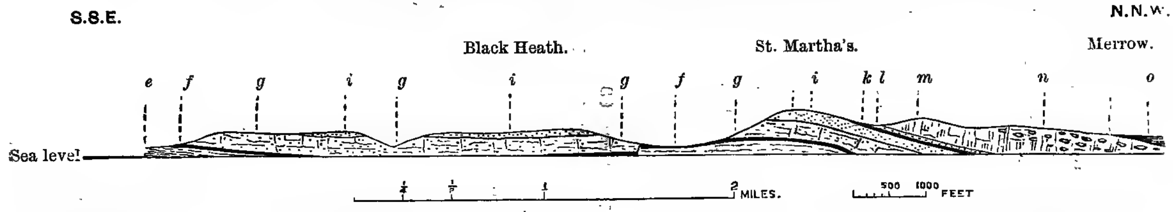


FIG. 5.—*Section through Black Heath and St. Martha's, south-west of Dorking.* (W. TOPLEY.)[1]
To show continuation of the Hog's Back anticline.



o. Tertiary. *m.* Middle and Lower Chalk. *k.* Gault. *e.* Weald Clay.
n. Upper Chalk. *l.* Upper Greensand. *f. g. i.* Lower Greensand.

[1] Geology of the Weald, Fig. 45, p. 230

It re-appears in the Vale of Kingsclere, which may be described as a local bulging of the flexure into an oblong pericline; the length of the tract of Upper Greensand exposed in this inlier is about five miles; the dips to the north are very steep, but those to the south are gentle, as is so often the case.

Whether this axis dies out in Hants or not is difficult to say, but in any case it is barely apparent along the western border of the Wealden area. It is probable, however, that the uplift of the valley of the Wey, which pitches so steeply northward below the ridge of the Hog's Back, is another bulge along the same line of disturbance (Fig. 4). The following account is quoted from Mr. Topley's Memoir:—"The crest of this flexure apparently begins near Bentley, and goes along the valley of the Wey past Farnham to Compton, at the western end of the Weald Clay inlier at Pease Marsh. On the northern side of this line the dip is very high, sometimes exceeding 40°. On the south side the dip is less, and the beds are sometimes flat or only slightly rolled over. On the east of Pease Marsh the line is prolonged past Albury Park, where it is distinctly anticlinal, towards Wotton." (*See* Fig. 5, which is taken from the same Memoir.)

This flexure appears to die out near Abinger; at any rate, it is not traceable further in that direction, but the anticline described by Mr. Topley as running through Bidborough and Brenchley may be developed along the same line of disturbance.

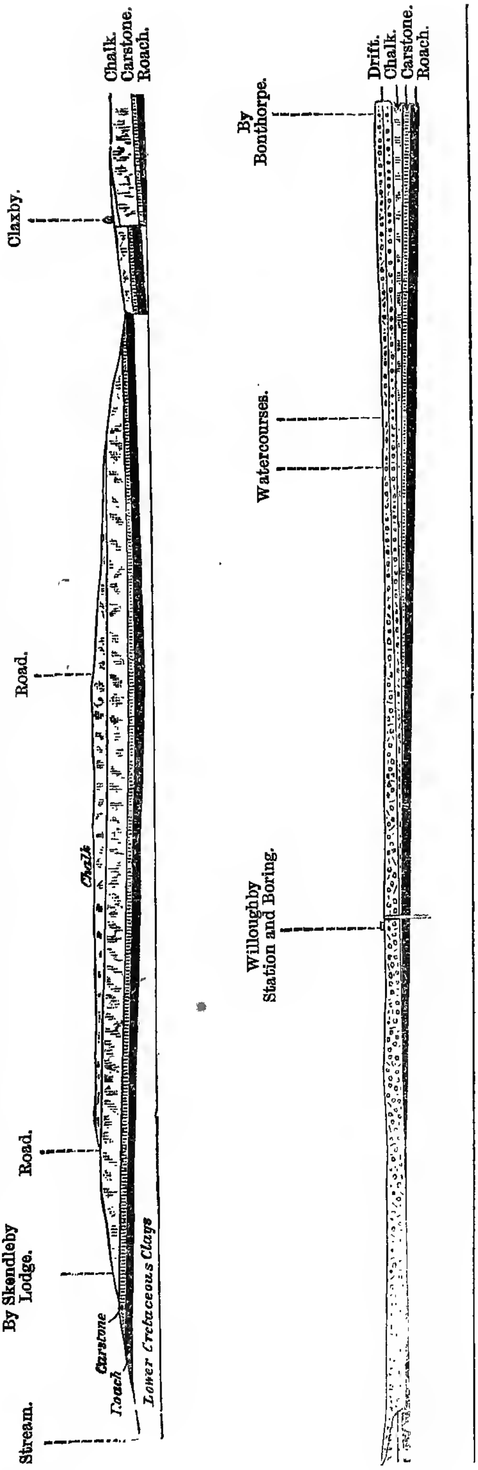
From the great uplift of the Wealden area the Cretaceous rocks pass beneath the corresponding trough or syncline of the London Basin, and north-west of this we have the long range of the main escarpment of the Chalk, forming the Chiltern Hills and their prolongation through Hertfordshire, Bedfordshire and Cambridgeshire.

North of the London Basin there are no great flexures comparable with those of southern England, the only flexure worth noting being one running from near Royston eastward to the valley of the Cam. Beyond this the Cretaceous strata spread out through the counties of Cambridge, Suffolk and Norfolk, with only some slight and local undulations, and having otherwise a gentle but steady inclination to the east.

The separation of the Lincolnshire Wolds from the Norfolk plateau is due to a slight uplift, along an east and west axis, which produces northerly dips along the southern boundary of the Cretaceous beds in Lincolnshire. The southern end of the Lincolnshire Wolds from Candlesby to the valley of the Calceby beck is a shallow synclinal basin, flanked on the east by an anticline which brings up the Lower Cretaceous Series below the Drift Deposits (see Fig. 6). The direction of these flexures is from N.W. to S.E.

The main escarpment in Lincolnshire has a similar trend, and the outcrops in Lincolnshire and Yorkshire evidently form part of one large basin, the central axis of which lies beneath the sea, and has the same direction as the smaller axes above mentioned. This basin is terminated on the north by an anticline which has

FIG. 6.—*Section from Skendleby Lodge through Claxby and Willoughby*[1], *Lincolnshire.*



[1] From Quart. Journ. Geol. Soc., vol. xlix., p. 475.

an east and west axis coinciding with the direction of the Vale of Pickering.

It remains only to describe the flexures which have determined the arrangement and lie of the south-western outliers of Cretaceous beds in the counties of Dorset and Devon. The great syncline of the Hampshire basin terminates in West Dorset rather abruptly, and is succeeded by a periclinal area the curvature or dome of which is but small, yet it exercises an important influence on the physical geography of the country.

On geological maps this pericline is indicated by an area of Jurassic rocks from which all traces of the Cretaceous strata have been removed, but which is bordered by outliers of these strata on the north, west, and south, while eastward it slopes beneath the escarpment in which the Hampshire basin terminates. This pericline is shown in Fig. 7; in its western part there is a low-lying tract of Liassic clays, about five miles long by three broad, which is known as the Vale of Marshwood, and bears some resemblance in its general features to the Weald of Kent and Sussex, only on a miniature scale.

West of this again is an area including parts of Dorset, Somerset, and Devon, in which there are many irregular outliers of the Cretaceous strata. Their irregularity is partly due to a number of faults and minor flexures, but more largely to the general high level of the Cretaceous tract and its consequent dissection by the valleys of the brooks which drain into the rivers Axe and Otter.

On the north is the high ridge of the Blackdown Hills, and in the south between Lyme Regis and Branscombe there is a decided tendency to a synclinal arrangement; indeed the isolated tracts of Chalk round Rousdon and Beer may be regarded as part of a basin the centre of which has been invaded by the sea. It is not unlikely that some Chalk occurs *in situ* below the sea to the south of the places above mentioned.

Still further west, between the valleys of the Exe and the Teign, are the Haldon Hills, which are capped by the most westerly outliers of the Cretaceous rocks in England. As might be expected, these appear to owe their survival to a slight synclinal flexure, and we may infer that the reason why no trace of these rocks remains in the area between the Otter and the Exe[1], is that this tract coincides with a slight anticlinal flexure of post-Cretaceous date, too slight to be noticeable in local dips, but sufficient to have lifted the Greensand to a higher elevation than it occupies in the Haldon Hills or in those near Sidmouth.

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[1] Two outliers of Upper Greensand are marked on the Geological Survey Map (Sheet 22), on Woodbury Common and on Black Hill north-west of Budleigh Salterton. These tracts, however, are no longer regarded as of Cretaceous age; they have been shown by Mr. W. A. E. Ussher to consist partly of New Red Pebble-beds and partly of Drift Gravel.

FIG. 7. *Geological map of the Vale of Marshwood, Dorset.*[1]
Scale, half an inch to a mile.

[1] Reduced from the Geological Survey map, and published in the *Geological Magazine* for 1898, p. 163.

CHAPTER II.

HISTORICAL ACCOUNT OF THE CHALK, UPPER GREENSAND, AND GAULT.

In this chapter I propose to give some account of the early investigations into the stratigraphical relations of the Cretaceous rocks, and of the difficulties experienced by the early geological explorers in their first attempts to correlate the several rock-groups in different parts of England. An explanation of the origin of the names which have hitherto been used for these rock-groups will also be given; few words are needful to explain the terms *Chalk* and *Gault*, but the history of the term *Upper Greensand* is a more complicated matter, and it has never yet been fully or accurately summarised. Its history is inseparably bound up with that of the *Lower Greensand*, and it involves the notice of a mistake which has prejudicially affected the nomenclature and classfication of the Cretaceous system in England.

Chalk.

The word chalk is derived from the Saxon *cealc* (German *kalk*), meaning lime, and it probably came to be applied to what we now call "the Chalk," because to the early Saxon invaders of the eastern and southern parts of England the Chalk was the most obvious and most easily accessible source whence to obtain a supply of lime for use in their buildings.

To this day the rock is called *kalk* by the country folk of Lincolnshire, but in southern England the word becomes softened into *chalk*, and as it was never applied to any other kind of limestone it came to have a definite and limited signification in the English language. It became in fact the English name for this particular material, a material for which in Germany a different word (*kreide*) had eventually to be employed. As a consequence of its already possessing this limited meaning, and of its being applicable in England to one single rock-mass or formation, it naturally became a definite geological term, and was very early employed as such; by Martin Lister, for instance, in 1684.

Gault.

This is a provincial name employed in Cambridgeshire, Suffolk, Hertfordshire, and perhaps some other counties, for a stiff blue clay. The origin of the word is doubtful, but may perhaps be connected with the German *kalt* (cold), from such a clay forming what agriculturists term a cold soil. It is variously spelt *Gault, Galt*, or *Golt*, and the first use of it in a geological sense was by the Rev. John Michell, who lived in Suffolk during the latter part of the last century. In 1760 he wrote a paper

on the "Cause and Phenomena of Earthquakes,"[1] in which he showed that he had a clear perception of the regular succession of stratified rocks; and among his papers was found a list of English strata bearing date 1788 or 1789, of which the first three names were—

Chalk - - - - -	120 yards thick
Golt - -	50 " "
Sand of Bedfordshire - -	10 or 20 " "

It was not, however, till some 30 years after this date that the name Gault became definitely attached to this particular clay.

William Smith, who began his researches in the neighbourhood of Bath in the year 1790, does not seem at first to have distinguished the Gault by any particular name, and the highest members of the succession, which he had "examined and proved prior to 1799," are called simply (1) Chalk, (2) Sand, (3) Clay.[2]

Thomas Webster, describing the Isle of Wight and writing in 1811 (though his letters were not published till 1816[3]), mentions the Gault under the name of the *Blue Marle*, and this name seems to have been adopted by W. Smith, for in his Memoir of 1815 (above quoted) it is so called in his table of strata, and is described as "Blue marl, so kindly for the growth of oak as to be called in some places the oak tree soil."

In his "Stratigraphical System of Organised Fossils," published in 1817, Smith calls it the "Brickearth" and gives a list of localities for Brickearth fossils (p. 36) in Surrey, Wilts, Bedford, and Bucks, all the places mentioned being on the Gault. But soon after this date he seems have become aware of the name Gault, and of the identity of the clay called Gault in Suffolk and Cambridge with his Brickearth, for in his maps of Kent and Surrey, and in his "Section of the Country from London to Brighton," all published in 1819, he calls this the "Golt Brickearth."

It may have been Prof. Hailstone who called his attention to this identity, for that writer described the Gault of Cambridgeshire under that name in 1816.[4]

The Greensands (Upper and Lower).

When the term *Greensand* was first introduced is a little uncertain, though there is no doubt that it originated with William Smith between the years 1800 and 1812, and it is also certain that both he and Thomas Webster always used it to designate the green sands which lie between the Chalk and the Gault.

In Smith's earliest Table of Strata (1799) these beds are simply called "Sand," and in a curious book written by the Rev.

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[1] Phil. Trans., Vol. li. p. 566.

[2] Table of strata near Bath given in the Memoir accompanying his Map of England and Wales, 1815.

[3] In Sir H. Englefield's History of the Isle of Wight, 1816.

[4] The Geology of Cambridgeshire, Trans. Geol. Soc., Vol. iii. p. 249.

J. Townsend,[1] who was a friend of Smith's and Rector of Pewsey in Wilts, we have an account of the geology of the west of England as known to Smith at the beginning of the century. In his preface the author says "the person by whom he was first led to trace the succession of strata in our island is William Smith. . . . . It is now eleven years since he conducted the author in his examination of the strata which are laid bare in the immediate vicinity of Bath. Subsequent excursions in the stratified and calcareous portions of our island have confirmed the information derived from this examination."

In Townsend's book all the Cretaceous strata below the Chalk are classed as "The Sand," which, however, he divides into three portions and names them in descending succession, thus :—

1. The *green* sand (of the Vales of Pewsey and Warminster).
2. The *grey* sand (of Devizes, Potterne, and other places).
3. The *red* sand (of Seend, Sandy Lane, and other places).

He was also fully aware of the existence of clay and brickearth between the red and the grey sand, but seems to have regarded it as only a local stratum in the sand-group; evidently thinking that in some places the red and grey sands came together and formed a continuous series, as is shown by his account of the Lulworth section. He expressly mentions the existence of *firestone* in the grey sand and gives a section of the large quarries at Merstham in Surrey. Finally he figures some of the fossils of the "green sand," and among them *Pecten asper* is recognisable under the name of *Ostrea muricata.*

The first complete account of the Cretaceous sequence in the south of England was an essay by John Middleton, first published in the *Monthly Magazine* for 1812, under the title of "Outlines of the Mineral Strata of Great Britain,' and subsequently in a history of the county of Surrey by Manning and Bray, vol iii., 1814. His measurements seem to have been taken in Swanage Bay, and he gave local names to several of his groups, remarking that the same set of beds occurs in the Weald, in Dorset, and in the Isle of Wight. The following is a summary of part of his sequence :—

		Feet
6. Chalk	Upper part with black flints - -	600
	Lower part with grey flints, and with layers of hard chalkstone and soft firestone at the base. - - -	200
7. Blue clay or marl, below the Chalk	- -	30
8. Fuller's Earth Sand or Reigate Sand	-	413
9. The Aluminous or Weald Measures	-	457
10. The Purbeck Strata -	- -	410

It will be noticed that the term Firestone, not Greensand, is used, and that it is grouped as part of the Chalk. On the other hand, the Reigate Sand is correctly placed below the Blue Marl and distinguished from the Weald Measures and from the Purbeck Beds.

[1] The Character of Moses Established for Veracity as an Historian. 4to. (London and Bath, 1813.)

Moreover he correctly identifies the Reigate Sand with the beds occupying the same position below the "blue marl" in Sussex, Kent, the Isle of Wight, Dorset, Hertfordshire and Bedfordshire, thus anticipating the results of Fitton's work by twenty years.

Webster's Letters on the geology of the Isle of Wight have already been mentioned. They were written in 1811 but not published till 1816; in them he correctly described the succession of rocks under the following names:—

Chalk.
Greensand or Firestone.
Blue Marl.
Ferruginous Sands.

It is clear, therefore, that the name Greensand was in verbal use by him and W. Smith before 1811, and that both correlated it with the Firestone of Surrey.

In 1815 Smith published his general map and memoir.[1] In this the Cretaceous strata are arranged as follows:—

Chalk {upper part soft, contains flints.
lower part hard; none.

Greensand parallel to edge of Chalk.

Blue marl.

Purbeck stone, Kentish rag and Limestone of the Vale of Pickering.

Iron Sand and Carstone, which in Surrey aud Bedfordshire contains Fullers' earth, and in some places Yellow Ochre and Glass sand.

It would seem from this that Smith was unaware of Middleton's names and of his correct determination of the position of the several formations below the Gault; for he makes only two groups instead of three, and each of them is a medley of uncorrelated strata. It is, however, perfectly clear that his "Greensand" is above the "Blue Marl" or Gault (*see* p. 20), and he remarks that it contains "Firestone and other soft stone sometimes used for building."

Two years later, in 1817, Smith published his well-known "Stratigraphical System of Organised Fossils," a work in which he more fully explained those principles of stratigraphical geology which he was the first to discover and employ. This book contains a numbered list of strata, which was meant to serve, not only as a tabular view of the succession of rock-groups, but as an index to his geological collection and to the maps which he was then preparing, many of them appearing between

[1] Memoir to the map and delineation of the Strata of England and Wales 4to. London, 1815.

1818 and 1821. The following is a copy of the first part of this table:—

Names on the shelves of the geological collection.	Colours.	Names in the Memoir [of 1815].
1 London clay	—	London Clay
2, 3, 4 Crag	—	Clay or brickearth, sand and Light loam
5 Chalk	Green	Chalk
6 Greensand	—	Greensand
7 Brickearth	Blue	Blue Marl
*8, 9, 10 Portland Rock	Three colours shown.	Purbeck Stone, Kentish Rag, &c.
11 Oak Tree Clay	Blue	
12, 13 Coral Rag & Pisolite	Two colours	Iron Sand, Carstone, &c.

The first column (with the numbers attached) gives the names he had adopted, and it will be seen that he made no change in the Upper Cretaceous series, except in using the name *Brick-earth* instead of *Blue Marl* for the Gault. The Greensand fossils mentioned by him are those of Warminster and Blackdown. His brickearth fossils include the small characteristic Belemnites, and by them he recognised the Gault near Reigate and Godstone in Surrey, near Devizes in Wilts, and at several localities in Bedford and Buckingham.

The sequence given in his table is evidently that between Bath and Devizes, for it so happens, that in that district, the Portland Sands, and the Lower Greensand, are so intimately associated that the first explorer would naturally regard them as one set of beds. The name of "Oak Tree Clay," which in his Memoir of 1815 he had used for the Blue Marl or Gault, he now transfers to the Kimeridge Clay.

It was not till the year 1818 that any confusion arose with regard to "The Greensand." The reader may be reminded that Smith, Townsend, and Webster had always been perfectly consistent in the application of that name to the sands immediately below the Chalk; that all of them were aware that the firestone beds of Merstham occurred in these sands, and that the Blue Marl lay below them. Further they knew that the Kentish Rag lay below the Blue Marl.

The two geologists who misapprehended the position of the Greensand in the Wealden area are William Phillips and Dr. Mantell.

Phillips' description of the Dover cliffs[1] contains an excellent account of the Chalk and its sub-divisions, but he seems to have overlooked the green sandy marl at the base of the Chalk, and to have thought that his "Grey Chalk" passed down into the "Blue

[1] Remarks on the Chalk Cliffs in the neighbourhood of Dover, and on the Blue Marl covering the Greensand near Folkestone. Trans. Geol. Soc., Vol. v. p. 16 (1821) Read in 1818

Marl" of Folkestone, which he describes as resting on "the greensand which is known in many parts of England to underlie the Chalk." Thus he took what we now call the Folkestone Beds to be the equivalent of the "Greensand" of Wiltshire, instead of identifying it with the Kentish Rag group; although he was aware that his Blue Marl was the same as the Gault, and ought to have known that Smith had always found his Greensand to be *above*, and not below it.

In the same year Dr. Mantell published "A Sketch of the Geological Structure of the South-eastern part of Sussex,"[1] in which he associates the Blue Marl with the Chalk Marl, placing "the Greensand" below it. At the same time he was evidently acquainted with Smith's classification, for he inserts a "Brick-earth" below his Greensand and a "Blue Clay or Oak Tree Soil" below that, saying that the Brickearth "occurs in detached masses resting on the Oak Tree Clay."

His Blue Clay is the Weald Clay; the brickearth may be Atherfield Clay. and his "Greensand" is evidently the sand below the Gault or "Blue Marl." But to make his supposed sequence fit the facts visible at Eastbourne he has to assume that the Gault is entirely absent at that locality; thus speaking of the "Blue Marl," he remarks, "in some places, as at Eastbourne, it is wanting, and the Chalk Marl is there seen in actual contact with the Greensand, the fossils peculiar to each formation being intermixed at the line of junction."

Thus both W. Phillips[2] and Mantell, assuming there was only one "Greensand," both maintained (in opposition to W. Smith) that it lay below and not above the "Blue Marl." This mistake gave rise to a long controversy, which was only terminated by a compromise almost as unfortunate as the original mistake.

In the year 1818, Prof. Buckland published a folio sheet entitled "The Order of Superposition of the Strata in the British Islands,"[3] which formulates the views then current as to the succession of the Cretaceous Strata, and is useful in showing how much confusion had been introduced into the sequence which Smith and Webster had so nearly completed. Buckland's table is very complete and orderly, the whole succession of stratified rocks being divided into "formations," two of which include the Cretaceous series, thus:—

No. 4, Chalk Formation.	Upper Chalk, with many beds of flinty nodules. Lower Chalk, with few flints. Chalk Marl, Malm, or Grey Chalk.
No. 5, Greensand Formation.	Greensand. Tetsworth Clay. Iron Sand.

The lithological varieties of each group and the localities where each such variety occurs are given. Following Phillips, he

[1] Provincial Magazine for August, 1818.

[2] See De Basterot, Trans. Geol. Soc., Ser. 2, Vol. ii. p. 334.

[3] Appended to W. Phillips' "Outline of the Geology of England and Wales." 8vo. London, 1818.

groups the Folkestone clay with the Chalk Marl. He does not mention the term Gault, but proposes a new name (Tetsworth Clay) for the clay below the Greensand in Wilts, Berks, and Oxon. His Greensand includes not only the true (Upper) Greensand of Wilts, Berks, &c., but also what Phillips and Mantell had called Greensand in Kent and Sussex. Similarly his Iron Sand group includes not only the Hastings Sands, but the Fullers' Earth of Nutfield and the Woburn Sands of Bedfordshire. There is no mention of, or place for, the Weald Clay.

As Smith's maps of Kent, Surrey and Sussex were all published in 1819, just after the views of Phillips and Mantell were made known, it is interesting to find that they show a perfectly correct sequence, the names and numbers being the same in all, thus:—

5. Chalk.
6. Greensand.
7. Golt and Brickearth.
8, 9, 10. Sand and Sandstone.
11. Oak-tree Clay.
12. Sand and Sandstone.

He evidently supposed that the succession in these counties was the same as that which he had made out in Wilts, and consequently he identified his upper "sand and sandstone" group with his Portland Rock, of which he says "in this county [Kent] it is called Kentish Rag." For the same reason he supposed the clay below (which was afterwards called the Weald Clay) to be his Oak Tree Clay (*i.e.*, Kimeridge Clay). But these mistaken correlations do not invalidate the local succession, for the position assigned to the several groups is correct and the relation of the Greensand to the Gault is clearly stated.

This confusion regarding Gault and Greensand was perpetuated and extended by Phillips and his colleague Conybeare in their "Outlines of the Geology of England and Wales" (1822). The following is their classification for the beds below the Chalk:—

A. Chalk Marl.
B. Greensand.
C. Weald Clay.
D. Iron Sand.

As in Buckland's Synopsis, the Chalk Marl is made to include not only the true Chalk Marl but the Malm-Rock, Firestone and Gault all round the Wealden area. Their "Greensand" is for this district entirely Lower Greensand; while for the Isle of Wight, Dorset, Wilts and Berks their "Greensand" is the Upper Greensand, and in these counties they take the Gault to be their "Weald Clay" and the Lower Greensand to be their "Iron Sand." It is therefore quite clear that Conybeare and Phillips thought the beds in Kent and Surrey, which were afterwards called Lower Greensand, were the actual chronological equivalents of the beds originally called "Greensand" by Smith in Wiltshire

That this confusion arose from the misunderstanding by W. Phillips with regard to the Gault and Greensand at Folkestone will, I think, be clear to everyone who reads Conybeare's remarks on p. 149 of the "Outlines of Geology," in which he speaks of the great importance of correctly tracing the line of the greensand, and says that "this fortunately may be done without the possibility of error by following its course continuously from its section on the coast between Folkestone and Lympne." This he does, and on reaching the Merstham and Reigate district he writes, "we feel ourselves compelled to dissent from the opinions advanced by a writer [probably Webster], . . . who from the inspection of this single spot has pronounced the firestone beds which we assign to the chalk marle formation to belong to that of the green sand, and the range which we consider as the true green sand to be iron sand."

Dr. Mantell continued to participate in these mistaken views.[1] His first edition of "The Fossils of the South Downs" was published in 1822, just after the appearance of Conybeare and Phillips' "Outlines." In it, under the head of "Blue Chalk Marl," he refers to Phillips' statement that this marl rests on *the Greensand* at Folkestone, and he repeats his own peculiar view (published before in 1818) that the blue chalk marl (Gault) is wanting at Eastbourne and several other places, and that in these instances the grey chalk marl reposes immediately upon the greensand."

In his general table he groups the Iron Sand, Tilgate Beds, the Weald Clay and "the Greensand" under the head of "*Greensand Formations*," and under the head of "*Chalk Formations*" he gives the following series:—Blue chalk marl; Grey chalk marl; Lower Chalk; Upper Chalk. Lastly he regards the Malm Rock of Western Sussex as replacing a part of the Gault, a view which is very probable in itself, but which by his arrangement involves the error of placing the Malm far above the horizon of the Eastbourne Greensand.

Mantell's book had deservedly a wide circulation, and all who read it must have gained the distinct impression that "*the Greensand*" always lay below the Gault wherever the latter occurred, and that "the fossils of the green grey and ferruginous sands of Sussex" had a general agreement with "those of the chlorite Sand of Wiltshire and Devonshire" (op. cit. p. 77).

These erroneous views of the succession in the south-east of England continued to prevail until 1824, when Dr. Fitton published his "Inquiries respecting the Geological Relations of the beds between the Chalk and the Purbeck Limestone in the South-east of England." [2]

In this the complete succession of the Cretaceous Series is clearly and correctly stated, and the strata of the Wealden area

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[1] The reader will understand that I have no wish underrate or detract from the value of the geological work done by Phillips, Conybeare, and Mantell; it was in fact the high value of their works which gave importance to this particular mistake and gained for it an acceptance which it might not otherwise have acquired.

[2] Ann. Phil., 2nd. Ser., Vol. viii. p. 365.

are for the first time rightly correlated with those of the Isle of Wight. He points out that whereas Conybeare and Phillips make only two sand groups, there are in reality three different sands separated by two distinct argillaceous formations, namely, the Gault and the Weald Clay. Unfortunately he retains the name of "Greensand" for the beds below the Gault because it had been "adopted so very generally by the geologists of England," although he admits that the character does not apply to the greater part of the group, and was fully aware that they had originally been described under the names of Iron Sand, Ferruginous Sands and Carstone.[1]

Fitton seems subsequently to have realised that he had in this paper perpetuated a mistake in reference to the use of the term Greensand, and he wrote a letter, published in the December number of the Annals, in which he says "It has been suggested to me from different quarters that the names *upper* and *lower* Greensand would be preferable for the denomination of the beds which I have named firestone and greensand; and that these two strata together with the intervening gault might form one group in the general arrangement under the name of the greensand formation. But the application of the term *greensand* has really been the source of so much confusion, that it seems much better to give it up altogether and to choose for the beds in question names entirely new—I know indeed that some of the principal geologists in England concur in this opinion." He then suggests the name *Merstham Beds* for the firestone and upper greensand, and the name *Shanklin Sands* for what he had previously termed "Greensand."

Webster appears to have been one of those who advocated, though he does not seem to have originated, the names Lower and Upper Greensand, for in a paper read by him to the Geological Society on the 5th Nov. 1824 he points out that "until lately the descriptions given by various geologists of the rock called *greensand* were supposed to be applied to one bed only, whereas in fact there are two beds distinct from each other, the undercliff of the Isle of Wight, and the rock of Folkestone, each of which had received this denomination." He then gives a table of equivalent beds, of part of which the following is a copy from the abstract in the same number of the Annals of Philosophy which contains Fitton's "Additional Remarks"[2]:—

Localities in the Isle of Wight.	Localities in the S.E. part of England.	Names proposed for the equivalent beds.	
Undercliff -	Reigate, Merstham and Beachy Head	Upper Greensand -	Greensand formation.
Ditto - - -	Folkestone Cliff -	Blue marl of the greensand - - - -	
Redcliff, Atherfield and Blackgang	Folkestone, Leith Hill, &c.	Lower greensand or ferrugino-greensand	

[1] It should be specially observed that Sedgwick, writing on the Isle of Wight in 1822 (Ann. of Phil., 2nd Ser., Vol. vi.) followed Webster's use of the names Greensand and Ironsand.

[2] Ann. Phil., 2nd Ser., Vol. viii. p. 465.

Again, in his "Reply to Dr. Fitton," written in 1824, but not published till January 1825,[1] Webster accepts the responsibility of proposing these names. He takes pains, however, to establish the right of the upper sands to the name of "Greensand," summing up his remarks in the following passage, which is well worth quoting:—

"Thus we see that almost everywhere below the Chalk in England (or rather below the chalk-marl according to my arrangement) there is a stone composed of siliceous grains, mica and dark green particles with a calcareous cement. In some places it is very hard; in others soft and fit to be employed as firestone; and in others again too soft for this purpose, and scarcely distinguishable from the common chalk-marl into which it sometimes passes. . . It is to this bed, as it appears to me, that the name of *greensand* was originally given by English geologists; and from the above and similar observations I conclude that the greensand bed in the Vale of Pewsey is the same with the rock of the Undercliff (Isle of Wight) and with the Reigate stone."[2]

With respect to the sand below the Gault he says, "If this bed be found to agree with the *ferruginous sand* of the West it would seem right that it should retain the original name. . . However, as it has been called Greensand by some eminent geologists, and since indeed it contains in some places a great quantity of the mineral from which the name has been derived, I have proposed in a paper lately read before the Geological Society to style it the *lower greensand*, or (to compromise the matter) *ferrugino-greensand*, the Undercliff being called the *upper greensand*. By this arrangement a group will be formed which may be called the *greensand formation*, consisting of the upper and lower greensands; and the blue marl between them will be called the *marl of the greensand*. This marl has indeed considerable analogies in its fossils with the bed above it, into which it sometimes passes."

This revival of Buckland's idea of a "Greensand formation" was not well advised, because it perpetuated a mistake and associated under a common name beds which ought to have been quite dissociated from one another. He seems to have changed his opinion during the preparation of the paper, for in the accompanying map and section he records his original classification, which was as follows:—

Chalk and Chalk Marl.
Greensand.
Blue Marl.
Ferruginous Sands { Upper ferruginous sand. / Weald Clay. / Lower ferruginous sand. }

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[1] Ann. Phil., 2nd. Ser., Vol. ix. p. 33.

[2] The Reigate-stone of Webster was the Firestone of the Upper Greensand, not any part of the Lower Greensand. In 1819 he had written a paper "On the Geognostic Position of the Reygate Stone," published in Trans. Geol. Soc., Vol. v. p. 353 (1821).

It was a pity that he abandoned this arrangement, in which the Lower Greensand was correctly associated with the rest of the Lower Cretaceous series. If he had only accepted Fitton's name of "Shanklin Sands" or had revived Middleton's name of Reigate Sands, and had insisted on the restriction of the name Greensand to the beds above the Gault, much misconception would have been avoided and a more rational nomenclature would have come into use. Webster therefore was responsible for the introduction of the names Upper and Lower Greensand, and the first person to employ them in a descriptive paper was Mr. (afterwards Sir Roderick) Murchison, the paper being one on the geology of the Western end of the Weald (read in 1825).[1]

In this he says, "It is the more necessary to define accurately all the strata of this district inasmuch as three of the formations have hitherto been described to be one range of greensand; whereas the upper greensand is divided from the lower, throughout the whole of this country, by a distinct and important breadth of *Gault clay*, of which the royal forest of Alice Holt forms the north-eastern portion." Of the Upper Greensand he says, "This formation is provincially termed Malm Rock, and is known by that name alone in the counties of Hants and Sussex throughout a range of 40 miles."

Murchison's adoption of these names was not, however, immediately followed by other geological writers.

In 1827 Mantell published the second edition of his book on the South Downs under the wider and better title of "Illustrations of the Geology of Sussex," and in this he confesses that he had made mistakes, and that some of the beds mentioned in 1822 as belonging to the "Greensand" really belong to the "Firestone," and not to the Shanklin Sands. When writing this edition he seems to have been of the same opinion as Dr. Fitton, that the term Greensand was connected with so many mistakes that it would be better to abandon it altogether, consequently he does not use the name "Lower Greensand" at all. In the table on p. 3 he gives "Firestone or Upper Greensand" in its proper place between the "Grey marl" (*i.e.* Chalk marl) and the "Gault or Folkestone Marl," though he still brackets everything from the Gault upwards under the head of "Chalk." On p. 17 he more minutely describes it as "Firestone or Merstham Beds (Greensand of the former volume)."

Instead of *Lower Greensand* he adopts the term "Shanklin Sands" for what he had called "Green or Chlorite Sand" in the volume of 1822. Thus he uses the names proposed by Fitton in his letter to the Annals of Philosophy in place of the nomenclature proposed by Webster and adopted by Murchison.

The inconvenience of Webster's nomenclature was also perceived by P. J. Martin who proposed a curious modification of it in his

[1] Trans. Geol. Soc., Ser. ii. Vol. ii. p. 97.

Memoir on Western Sussex, published 1828, his table of the Greensand or "Glauconite" groups being as follows:—

Glauconite	Malm - - -	Upper Greensand. / Malm-rock.
	Gault.	
	Shanklin Sands	Ferruginous sand. / Lower Greensand.

thus degrading the names upper and lower greensand from primary rank and applying them to local subdivisions, He justifies his choice of name "Malm" in the following terms:— "Dr. Fitton, the accurate explorator of these formations, has made use of the word firestone, but has since abandoned it, and seems disposed to adopt that of upper greensand. Mr. Murchison, who has used the nomenclature of Dr. Fitton and made out the best suite of fossils from this stratum, makes more use of the word malm-rock than of the adopted name of firestone; and in all the great development of it reviewed by him in Hampshire and Sussex the malm-rock, provinciallv so called, predominates over the greensand and hard slate-coloured marl, its subordinate members. In this unsettled state of things, and being at liberty to choose, the word '*malm*' has been preferred to designate everything interposed between the chalk and the galt. First because the word itself, like galt, lias killas, &c., has no meaning or applicability beyond the thing signified, ... and secondly because it has acquired a classical character in its use by White, the naturalist of Selborne."[1]

The two divisions of the Shanklin Sands are shown by different colours on his map, and he speaks of the lower division as the "true lower Greensand." His arrangement is really a correct and rational one for the area described, but would not apply to other areas.

In the year 1832, therefore, there were really three different nomenclatures in use for this part of the Cretaceous series, as shown in the following table:—

Webster and Murchison.	Fitton and Mantell.	Martin.
Upper Greensand.	Firestone or Merstham Beds.	Malm.
Gault.	Gault.	Gault.
Lower Greensand.	Shanklin Sand.	Shanklin Sand.

In 1833 Mantell published a handy little volume entitled "The Geology of the South-east of England," which is perhaps less known than it deserves to be. In this book, although he retains the names he had used in 1827, he adds Webster's names as synonyms, and at the head of Chapter v., p. 66, they are given as follows:—

Firestone or Upper Greensand.
Gault or Folkestone Marl.
Shanklin or Lower Greensand.

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1 See White's Natural History of Selborne, first letter.

In 1836 appeared Fitton's well-known and detailed memoir, "On the Strata between the Chalk and the Oxford Oolite."[1]

In this he adopts the names of *Upper* and *Lower Greensand*, prefacing his table with the following remark. "The following arrangement and subdivisions may be adopted, the nomenclature of which, however exposed to criticism, is now probably too well established to be changed without inconvenience"; and in a note he especially refers to the faultiness of the term *greensand*. This memoir was read in 1827, but it was largely altered and added to before publication. It is possible, however, that he had used Webster's names at that date, for they are also used by Lonsdale in his memoir on the country round Bath, which was prepared partly at the instance of Dr. Fitton and was read in 1829.

When the misunderstandings which had gathered round the term "Greensand" had been dispelled, and when the true or "upper" Greensand had been distinguished from the "lower" Greensand, it was supposed that the two Greensands were everywhere separated from one another by the Gault or "Folkestone Marl." It was, however, known that the beds called "Upper Greensand" did not everywhere consist of sand, and some authors describing districts where *malmstone* and *firestone* were conspicuous members of the group gave prominence to these as names for a part of it. But after Fitton's definite adoption of the names Gault and Upper Greensand in 1836, these came into general use and were adopted by the Geological Survey from 1839 onwards.

The earliest sheet of the Geological Survey map on which Upper Greensand was coloured is sheet 22 (Devon) surveyed by Sir Henry De la Beche and published before 1845; the first sheet on which both Gault and Greensand were shown is that numbered 15, which includes Shaftesbury and the Vale of Wardour, published in 1856.

With respect to the adoption of the Gault and Greensand as separate subdivisions of the Cretaceous series by the Geological Survey, it must be remembered that these names lent themselves admirably to the practical purposes of the Survey. It was in fact inevitable that the clays and the sandy beds should be separately mapped and that different colours should be assigned to them; and if names had not already been given to them, others would doubtless have been suggested.

What, however, the early surveyors did not realise was that these subdivisions were of subordinate rank and without any definite chronological importance. A lithological division of the Upper Cretaceous Series into (1) Gault, (2) Upper Greensand, (3) Chalk, was made without any regard to the proportional time values of such groups and without due enquiry into the stratigraphical relations of the Gault and Upper Greensand in particular.

By one man, however, the relations of the Gault and Upper

[1] Trans. Geol. Soc., Ser. ii., Vol. iv. p. 103. See also Letter from Fitton, published in the "Life and Letters of Sir J. Prestwich," 1899, p. 80.

Greensand were clearly perceived; this was Mr. Godwin-Austen in 1850,[1] who warns his readers against the idea of their being definite rock-groups, adding that "indeed there is no name in the whole series of geological formations so purely conventional as that of Upper Greensand"; again he says, "the differences between the fauna of the Devizes and Blackdown Beds and that of the Upper Gault of Folkestone are only such as might be expected between arenaceous and argillaceous portions of the same zone. The Gault, moreover, is not an independent formation, but merely the accumulation of a given condition of deep sea, synchronous as a whole with that portion of the Cretaceous deposits which we call 'Upper Greensand.'"

This is a remarkable declaration expressed in language which could hardly be improved at the present day after a lapse of 50 years. Mr. Godwin-Austen had evidently recognised the palæontological differences between the Upper and Lower Gault of Folkestone, though I cannot find that anyone had published any data for such a conviction prior to 1850. Indeed Mr. Godwin-Austen's expression of opinion with regard to the equivalency of Gault and Upper Greensand seems to have made but little impression upon the systematists of the time, probably for the very reason that it was a sort of *obiter dictum* in a paper on another subject, and that he never supported it by any express publication of the facts on which it was based.

This is much to be regretted, for there can be no doubt that the continued use of the lithological classification without any explanation perpetuated the error that lurked behind it; moreover an unfortunate suggestion that the Upper Greensand might be a shore deposit of the age of the Chalk Marl,[2] doubtless tended to counteract Godwin-Austen's more accurate view, and to encourage the idea that the Upper Greensand was of more recent date than any part of the Gault.

Thus it came to be generally supposed that the Gault at any rate was a definite and distinct formation, worthy to rank as a primary division of the Cretaceous System, and that it must always be overlain by some representative of the Upper Greensand. It was assumed, for instance, that the Gault of Folkestone was, as a whole, older than any of the beds classed as Upper Greensand in the Wealden Area; and further that the Gault of one district was equivalent to "the Gault" of any other district. Hence it was supposed that the Gault of Wiltshire was a complete representative of the Gault of Kent or of Bucks, whereas the truth is that the Wiltshire Gault represents only the lower portion of the Gault of those counties.

These ideas seem to have prevailed till about the year 1866, and the publications which have chiefly contributed to the formation of more accurate views respecting the Gault and Upper Greensand are the following:—

(1.) Notes on the Correlation of the Cretaceous Rocks of the South-east and West of England, by Mr. C. J. A. Meyer (1866).[3]

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[1] Quart. Journ. Geol. Soc., Vol. vi. p. 461 and p. 472.
[2] Mentioned in the first edition of Jukes' Manual of Geology, 1857, p. 506.
[3] Geol. Mag., Vol. iii. p. 13.

In this we find it stated that "the Gault or Folkestone Marl . . . thins out so considerably to the west of Reigate as to favour the idea that this bed is, in spite of its great extent, but a subordinate member in the Cretaceous series." Again he says, "Passing further to the westward, I should suppose the Gault to be partly represented in the vicinity of Lyme Regis by the 'yellowish-brown sand or Fox-mould.'" These views are illustrated by a diagram or "ideal section" of Cretaceous Rocks in the range from Folkestone to Lyme Regis.

(2.) Papers by Mr. C. E. De Rance[1] (1868) and Mr. F. G. H. Price (1874)[2] describing the Gault of Folkestone and the zones into which it is divisible. They agree very closely, and show that the fauna of the lower 30 feet differs considerably from that of the remainder. Mr. Price states that out of 240 species known to him, 124 are confined to the Lower Gault and 59 to the Upper. These papers supply the detailed evidence for the conclusion which Mr. Godwin-Austen seems to have arrived at in 1850.

(3.) A paper on the "Relations of the Cambridge Gault and Greensand,"[3] in which I showed that the so-called "Upper Greensand" of Cambridge was simply the basement bed of the Chalk Marl, and that its fossils had been derived from the Gault. Further that the true Upper Greensand dies out in Buckinghamshire and does not reappear as "greensand" to the north of that county. Lastly it was shown that the Gault of Bucks includes representatives of both the Lower and Upper Gault of Folkestone, while in the counties of Bedford, Hertford and Cambridge the Upper Gault has been destroyed by erosion and has yielded its fossils to form the nodule-bed of the overlying Cambridge Greensand.

(4.) The "Recherches sur le Terrain Crétacé Supérieur de l'Angleterre et de l'Irland," par Ch. Barrois (Lille, 1876), in which Dr. Barrois takes the zonal classification which had been worked out in France and employs it in a detailed description of the Chalk and Greensand of England and Ireland. Of the Upper Greensand of the Isle of Wight he writes (p 105), "I had thought that the lithological characters of the Upper Greensand would make it a special division distinct from the other zones. I was mistaken; in the Upper Greensand of the Isle of Wight, as in that of the rest of England, there are two very distinct faunas, that of Blackdown and that of Warminster." The Blackdown fauna he places in his *zone of Ammonites inflatus*, and the Warminster fauna in his *zone of Pecten asper*. Dr. Barrois indicated the respective portions of our Gault and Greensand which are referable to these two zones in all the southern counties of England, as well as in Wilts, Berks and Bucks.

He does not, however, include the Lower Gault in the Upper Cretaceous series, from the mistaken impression that the area occupied by the Gault sea coincided rather with that of the Neocomian sea than with that of the Cenomanian; so that he draws the line between Upper and Lower Cretaceous in the middle of the Folkestone Gault.

(5.) An examination of the Gault and Lower Chalk of Suffolk and Norfolk by Mr. W. Hill and myself in 1886,[4] from which we showed that beyond the erosion area of the Cambridge Greensand or "nodule-bed," the Upper Gault was again recognisable, both Lower and Upper divisions extending northward with a gradually diminishing thickness till they merged into the so-called "Red Chalk" of Hunstanton.

It had just previously been suggested[5] that the Gault was not represented in Norfolk, the marly clay so denominated being really Chalk Marl. We were, however, able to prove it to be really Gault by the

[1] Geol. Mag., Vol. v. p. 163. [2] Quart. Journ. Geol. Soc., Vol. xxx. p. 342.
[3] Quart. Journ. Geol. Soc., Vol. xxxi p. 256 (1875).
[4] Quart. Journ. Geol. Soc., Vol. xliii. p. 544.
[5] By C. Reid and G. Sharman. Geol. Mag., Dec. 3, Vol. iii., p. 55.

discovery of its characteristic Ammonites, and by indicating the glauconitic base of the Chalk Marl above this marly clay.

(6.) A paper by myself "On the Geology of Devizes, with Remarks on the Grouping of the Cretaceous Deposits."[1]

In this it was shown that the Gault of Devizes did not represent more than the Lower Gault of Folkestone, that the fossils of the overlying micaceous sandstones proved them to belong to the zone of *Ammonites inflatus* (as indeed Dr. Barrois had already stated), and that the highest sands represent the Warminster beds or Barrois' zone of *Pecten asper*.

It was also maintained that those were right who regarded the Gault and Upper Greensand as merely different lithological facies of one group or stage in the Cretaceous series, and that if we continued to use the two names as if they were separate chronological units in the time-scale of the Cretaceous system, we should be giving a wrong interpretation of Nature's facts. It was pointed out that a new name for this united Gault and Greensand formation would eventually be required, that Devizes was well fitted to be regarded as a type locality, and without definitely proposing the name *Devisian*, it was suggested that such a name might be found a convenient one.

In 1892 the view of a united Gault and Upper Greensand was accepted by the Director General of the Geological Surveys,[2] who remarked that the opinion of their being parts of one formation, held by Mr. H. W. Bristow, Mr. Godwin-Austen and others, had "received support from our recent surveys."

In 1896 I wrote as follows:[3]—"It is now recognised by the Geological Survey of Great Britain that the Gault and Upper Greensand can no longer be regarded as separate stages or chronological divisions of the Cretaceous System. To speak of the 'Gault' as a formation distinct from and older than the Upper Greensand is simply a mistake, for there can be no doubt that what is called Upper Gault in the east of England is coeval with Upper Greensand in the west. They are merely different lithological facies of one group of deposits, and in the systematic classification of the future a new name will have to be found for this Gault and Greensand formation."

With the publication of this Memoir it would seem that the time has come when the synchronism of the Gault and Upper Greensand should be fully acknowledged, and when the stratigraphical value of the group should be expressed by giving it a suitable name, so that it may take rank with the other natural groups or stages of the Upper Cretaceous Series.

We wish that it had been possible to adopt the French name of *Albian* which was used for the Gault of Folkestone by Mr. De Rance in 1868; and if French geologists had not subsequently restricted the application of the name there would have been no reason why it should not be employed in England.

There is no doubt that the Albian of d'Orbigny, Leymerie and their contemporaries included the upper clays of the Gault in

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[1] Proc. Wilts. Nat. Hist. Soc., Vol. xxv. p. 371 (1891); and Proc. Geol. Assoc., Vol. xii. p. 254 (1892).

[2] Annual Report of the Geological Survey for the year ending December 31, 1892, p. 252.

[3] Quart. Journ. Geol. Soc., Vol. lii. p. 170.

the department of the Aube as well as the "gaize" of the Meuse and Aisne; that is to say what is known in France as the zone of *Ammonites rostratus*. This grouping remained in general use until 1874, when Prof. Barrois proposed to separate these beds from the Albian and to regard them as part of the Cenomanian. In this he was greatly influenced by the views held by Professor Hébert, who had formed the opinion that the beds containing *Am. inflatus* at Havre belonged to the Cenomanian rather than to the Albian.[1]

The opinion of Messrs. Hébert and Barrois has since been widely adopted by French geologists, and in most modern French text-books of Geology the Albian is restricted to beds which correspond with our Lower Gault, while those corresponding with our Upper Gault and Upper Greensand are placed in their Cenomanian stage.

I have endeavoured to show that this separation of the zone of *Ammonites inflatus* is based on mistaken ideas both of the stratigraphical and palæontological relations of the beds concerned,[2] and it may be that another generation of French geologists will restore these beds to the Albian. In the meantime the views at present prevailing in France make it inadvisable to introduce the name Albian into English nomenclature.

Selbornian.

We are consequently obliged to propose a new name for the English type of the formation, and the name *Devisian* was first considered, but though the locality is an excellent one from which to derive a name for the whole formation, yet it so happened that a very similar name (*Divesien*) had been proposed by Professor Renevier in 1874 for a division of the Oxford Clay as developed at Divés in Normandy. As this name has come into use it seemed inadvisable to propose one so like it for a different formation in England.

After a consideration of all the place-names which are available, that of *Selbornian*, from the village made famous by the letters of Gilbert White, has seemed the most suitable and the most euphonious. Selborne is situated on the malmstone or malm-rock which constitutes an important member of the formation not only in Hampshire but also in the counties of Surrey, Sussex, Wilts and Berks. It is the "freestone" described in White's fourth letter from Selborne, and has been quarried in Hampshire for many purposes. The clays of the Gault are also well developed below the malmstone to the east of Selborne. The district was one of the first in which the true succession of the beds was described[3] under the names of Lower Greensand Gault and Upper Greensand.

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[1] Comptes Rendus de l'Acad. des Sciences, 1864 and 1866.

[2] Feuille des Jeunes Naturalistes, Ser. iii. (July and August 1898), and Natural Science, vol. xiii., p. 193 (1898).

[3] By Sir R. I. Murchison in Trans. Geol. Soc., Ser. ii. vol. ii., p. 97 (1825). See also Proc. Geol. Assoc., vol. xii., p. 192.

It is not intended that the name *Selbornian* shall supersede those of Gault and Greensand. To them it bears much the same relation as does the term *Wealden* to the Weald Clay and Hastings Sands. Just as it is found convenient to employ the name Wealden for the natural group of beds known as the Weald Clay and Hastings Sands, so it will be found convenient to employ the term Selbornian for the group which includes the Gault and Upper Greensand.

As a matter of fact *gault clay* and *greensand* are only two of the different kinds of deposits that make up the group for which the name Selbornian is now proposed; it is only by a stretch of the imagination that malmstone can be called greensand, inasmuch as an ordinary malm contains but a small proportion of quartz-sand and still less glauconite, so that it is not a sand nor is its colour green. There are large areas over which the formation is really a tripartite one, and could actually be mapped as consisting of *Gault*, *Malmstone* and *Greensand*; there are also areas where it consists wholly of Gault, *i.e.* of grey clays and marls; others again where it consists entirely of sand and sandstone; and finally there is a large area where it is neither one nor the other, but is represented by red chalky limestone and red marl.

For those who desire simply to treat the strata chronologically the names Gault and Upper Greensand will henceforth have little value: the group will be the Selbornian, and its subdivisions will be zones characterised by different assemblages of fossils. The nature and value of these subdivisions will be discussed in the next chapter.

CHAPTER III.

THE VALUE OF ZONES IN THE CRETACEOUS SYSTEM.

The advance which has been made in our knowledge of the Upper Cretaceous series during the last twenty years has consisted largely in the establishment of zones and in the tracing of them throughout England. It is fitting, therefore, that some account of this zonal method should be given in this memoir. Moreover, after the experience of many years in the constant endeavour to identify zones and to follow them from point to point, I desire to place on record some of the conclusions to which I have been led by a study of these Cretaceous zones, especially with respect to the proper conception of a zone, the use of an index species, and the limitations which must be placed to the zonal method.

The idea of zonal divisions is a natural outcome of William Smith's axiom that "strata may be identified by the fossil remains which they contain." From this general statement to evolve the idea of zones required only the further observation that while some fossils range through a considerable thickness of strata, others are limited to a portion of this thickness, and further that within a certain area (often of large extent) the same distribution and limitation of species holds good.

The first idea of such zonal distribution may be referred to Von Buch, who in 1832 published a treatise on Ammonites in which he showed that the vertical range of many species was very restricted. The subject was taken up and pursued in more detail by Quenstedt and Oppel, and the latter in 1856 was able to establish the existence of zones characterised by different species of Ammonites in the German Lias. The application of the same method to the study of the Cretaceous system seems also to have been first made by a German geologist. This was Von Strombeck, who worked out the Lower Cretaceous series of N.W. Germany between 1854 and 1858, and who subsequently wrote on the zones of the upper Cretaceous series.[1] The idea was taken up in France by Messrs. Hébert, Coquand and others (1864 to 1869), but in England the study of the Cretaceous Series was not pursued on these lines until after the publication of Dr. Barrois' researches in 1876.[2]

Definition of a Zone.

Zones have been defined in various ways, and we may trace a gradual growth of opinion from early indefinite and incorrect

[1] Ueber die Gault, &c., Zeitschr. d. deut. geol. Gesell. for 1861, p. 20.

[2] Récherches sur le Terrain Crétacé Supérieur de l'Angleterre et de l'Irlande, Lille, 1876. (Mem. Soc. Geol. du Nord.)

ideas about them to a clearer and more correct conception of their real nature. Thus most of the earlier English writers on the subject, like Dr. Wright, Prof. Phillips and Mr. Ralph Tate, used the term "zones of life," and it is probable that this imparted to other minds the impression that zones were merely zoological assemblages or faunas, and were only useful as indicating the succession of life-forms in a sequence of strata that had been established on a different basis.

Another phrase that was frequently used by some writers was "Ammonite zones," a phrase which naturally led to the fallacy that zones were established solely on the occurrence of certain species of *Ammonites*, without reference to the distribution of other kinds of fossils. Thus we find Prof. Phillips writing of Ammonite zones and Belemnite zones and recommending that the distribution of Echinoderms and Brachiopoda should be studied on the same method.[1] That this was not the conception of zones formed by those who were at that time working at those of the Lias, may be seen by referring to the papers and monographs of Dr. Wright[2] and Mr. Tate.[3]

It is interesting to notice that in his earlier paper (1867) Mr. Tate defines a zone as "an assemblage of species," but in his later paper (1875) he writes "the strata [of the Lias] admit of a grouping into zones after their palæontological characters, and further into regions of Ammonites, a classification as much in harmony with facts as that of the Oolitic rocks into formations."

The idea that a zone is essentially an assemblage of fossils has persisted in some minds up to the present day, but such statements as "zones are assemblages of organic remains of which one abundant and characteristic form is chosen as an index,"[4] and again, "they are assemblages of fossils that occur in a more or less definite sequence,"[5] are only partial definitions of a zone. It is undoubtedly true that the fossil assemblages occur in a sequence, and that though one or more of them may seem to be absent at certain places, this sequence is never varied or inverted, but these fossil assemblages are the zonal faunas and not the zones themselves.

As Mr. H. B. Woodward rightly observes, "the essential idea of a zone is that it marks, however roughly, a period of time"; it corresponds in fact with the period of time during which a certain assemblage of species flourished contemporaneously in one marine province, and this being so it must correspond with the time occupied by the deposition of the sediments which enclose this assemblage.

The very name zone conveys the idea of a band, not an assemblage, and it is more than an horizon or single bed. The

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[1] Geology of Oxford, 1879, p. 132.

[2] Quart. Journ. Geol. Soc., Vol. xvi. p. 374, and the volumes of the Palæont. Soc. for 1878 and 1879 (Lias Ammonites).

[3] Quart. Journ. Geol. Soc., Vol. xxiii. p. 300 (1867) and Vol. xxxi. p. 493 (1875).

[4] H. B. Woodward on Geological Zones. Proc. Geol. Assoc. Vol. xii. p. 298.

[5] The Jurassic Rocks of Britain. Mem. Geol. Surv., Vols. iii. p. 18; iv. p. 23.

[6] See remarks by Mr. J. E. Marr in "Natural Science," Vol. i. p. 128 (1892).

primary idea seems to be a band of stratified rock limited in depth, but having a great horizontal or geographical extension; and a definition of it must have primary reference to the strata and not to the fossils. Perhaps it may be defined as a band of sedimentary material within which certain species are either restricted or are specially abundant, and during the formation of which certain species acquired their greatest exuberance and their greatest geographical extension.

More than this, however, is implied by the modern idea of the term *zone*, for a zone is only one of several successive zones; it is not merely a specially fossiliferous band in a thick mass of sediment, but is a subdivision of such a mass or group of beds; such a group being generally divisible into two, three, or more zones, one succeeding another. Thus the correct idea of a zone involves three separate concepts—space, time, and life.

If reference be made to the best text-books of Geology that are current at the present day, it will be found that a zone is generally defined as a group of strata which contains a distinct and recognisable fauna, that it is regarded as a definite subdivision of a stage or of a formation, and is sometimes stated to be the unit of a chronological and stratigraphical classification.[1] Thus Prof. Lapworth states that Stages are "divisible into *Zones* or minor groups of strata"; Messrs. Kayser and Lake remark that "usually the smallest geological unit is taken to be, not the bed, ... but the zone." Lastly, Mr. J. E. Marr gives the following definition:—"Zones are belts of strata, each of which is characterised by an assemblage of organic remains, of which one abundant and characteristic form is chosen as an index."

This definition closely agrees with that I have formulated above, which was written before the publication of Mr. Marr's useful little treatise.

The Zonal Fauna.

When we write of the fauna of a zone we generally mean all the fossils which have been or can be found in the beds which are recognised as belonging to the zone. But what may be termed the critical fauna of a zone is the much smaller assemblage of fossils which are either restricted to it or are specially abundant in it. One of these species is then chosen as the index of the restricted assemblage of species, and the name of this fossil is given to the zone, so that we speak of it as the zone of this fossil, *e.g.*, the zone of *Ammonites varians*, or the zone of *Belemnitella mucronata*.

There is yet another point to be considered before we can form a true conception of a zone. If it is regarded as part of an extensive formation, and consequently as representing a certain

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[1] Consult Sir A. Geikie, Textbook of Geology, Edition 1, p. 635, and Edition 3, p. 678 (1893); Page and Lapworth, Introductory Textbook 1888, p. 125, and Lapworth, Intermediate Textbook, 1899, p. 155; Kayser and Lake, Textbook of Comparative Geology, 1895, p. 6; Marr, Principles of Stratigraphical Geology, 1899, p. 68.

part of geological time, we must be prepared to find much variation in the lithological characters of the beds which compose it. Being based on the occurrence of certain fossils, it is independent of lithological variations and is traceable through different kinds of deposit. Thus a zone which is part of a clay formation in one district may consist largely of marl or limestone in another or may pass wholly into sand.

We must also be prepared to find that a zone does not yield exactly the same assemblage of fossils, or of its critical fossils, in every district; even when the component material is similar, and much more when the beds consist of different material. There will be some species in the sandy beds which do not occur in the clays, and some in the limestones which do not occur, at any rate so commonly, in the sands and clays.

Hence the complete fauna of a zone is not likely to be known unless we can trace it through several different kinds of sedimentary deposits. A good instance of this is furnished by the zone of *Ammonites rostratus* in England. In Kent this zone consists entirely of clay and marl, in West Surrey and in Hampshire it consists chiefly of sandy marl and malmstone, in Wilts it is a succession of malmstone, gaize,[1] and sand, while in Devon it consists wholly of sand. In this zone we may distinguish at least three faunal facies, which we will call the Folkestone, the Devizes and the Blackdown facies, and each of them contains some fossils which are common only in the area occupied by that facies. As an instance we may mention *Pleuromya mandibula*, a species which is common in and characteristic of the zone in Wiltshire, but has never been found at Folkestone, nor at Blackdown.

Such facts teach us that a full collection of fossils from a single locality, or from a single lithological facies of a zone, will not furnish us with the complete fauna of the zone, considered as a palæontological division and as a portion of geological time. A neglect of this consideration has led to some mistakes, and the existence of different zonal facies sometimes makes the correlation of zones in different areas a difficult matter, especially if they are geographically isolated.

Index Species.

It has been mentioned that one of the characteristic species is chosen as the index of the zone. This is not necessarily a restricted species; it may be one which ranges into higher and lower zones, but which is specially abundant in the zone for which it is chosen as the index. *Inoceramus mytiloides*, which gives its name to a zone in the Middle Chalk, is a case in point.

It is often difficult to select a species which will be a satisfactory index for a zone over the whole country. It may happen that a species is particularly common in one district and is chosen as an index for the zone in which it occurs, while in another part of the country this species is much less common, and the person describing the zone in the latter district chooses

[1] See p. 54.

some other species as an index. In this way the same zone may have different index-names in different districts or in adjoining countries. Thus the zone which is known in England as that of *Rhynchonella Cuvieri* is known in France as the zone of *Inoceramus labiatus* (= *I. mytiloides*). Sometimes it is convenient to use both names, adopting two index-species.

Again, it may happen that a fossil may have a restricted range in one area, but a more extended one in another, consequently if it has been selected as a zonal index in the first area, it becomes necessary to take another fossil as an index in the second area. This is the case with *Holaster subglobosus*, which has a restricted range in certain parts of England and gives its name to a zone, but in the north-east it is commoner in a lower zone, so that it would only be misleading to retain it as an index for the higher zone in that part of the country. In such a case we may either select another species, *e.g. Offaster sphæricus*, and say the zone of *Offaster sphæricus* represents the zone of *Holaster subglobosus*, or we must abandon the use of the latter name and adopt that of some species which occurs in both areas.

The reader must be cautioned against becoming possessed with the idea that a zone is a set of beds characterised by the occurrence of one particular species, and that every bed which yields this index-species must belong to the zone. It must be remembered that this particular species is only one of several or many, and that it is this assemblage of species which is the guide to the zone.

Mr. Ralph Tate made some apposite remarks on this subject which are worth quoting.[1] He says "species of Ammonites have been selected as indices to the zones, but their presence alone does not warrant us in assigning this limestone to the zone of *Am. angulatus* or that clay to that of *Am. Turneri*, as the case may be; for they may range through several zones. The Ammonite which gives its name to a zone is but one of many which mark a determinate stage in the life-history of the formation. Hence the zone is a zoological one and signifies an assemblage of species, and whether you call it Lias α and Lias β, &c., or the zones of *Ammonites planorbis* and *Ammonites angulatus*, the succession of faunas in the Lower Lias still remains patent, and it is to these several faunas that the term Ammonite zone is applied."

This is true, except that the term zone should be connected more definitely with the *band* of strata which contains the special fauna. As Tate himself says, the zone may be called Lias α or Lias β, and it is the beds which constitute the zone.

Thus a zone may be traced continuously from an area in which fossils are abundant to one in which fossils are very rare and in which it is difficult to find any of the species which form the zonal assemblage. This actually happens in the case of the

[1] On the Lower Lias of Ireland. Quart. Journ. Geol. Soc., Vol. xxiii. p. 300 (1867).

zone of *Holaster subglobosus*, but the beds are there, and it would certainly be incorrect to say that the zone is absent.

Value of Zones; Sub-zones; Hemeræ.

The value and importance of a zone depends partly on the number of restricted species and partly on the extent of country over which it can be traced. The thickness of a zone is of course a stratigraphical accident, depending merely on the amount of sediment deposited at any locality during the life-time of the zonal fauna. Thus a zone may be in one area only a few feet in thickness, in another it may be 20 or 30 feet, and in a third it may expand into 200 or 300 feet.

Hitherto the term zone has been applied to bands of very different importance; some having a large number of restricted species, and a great geographical extension, with occasional expansion into formations which are several hundred feet thick; others are of small importance, being merely a few beds containing one or two restricted species and not traceable over a very large area.

Recently, however, it has been perceived that the latter are subordinate divisions, often local, but still component parts of a larger and more extensive zone. French geologists have sometimes used the term *niveau* (meaning horizon) for such minor zones, but *sub-zone* seems a better English name, and it has the advantage that it can be easily rendered in French as *sous-zone*.

Thus a broad and important zone will often include two or more sub-zones which may or may not be co-extensive with the zone. But it is only in localities in which a zone is especially fossiliferous that many sub-zones can be recognised. The Lower Gault clay of Folkestone, which is the equivalent of the French zone *à Ammonites interruptus*, presents an example of such sub-zones. Mr. F. G. H. Price has divided it into eight "beds," as he called them, most of which are really sub-zones, each characterised by certain species which are rare or absent in the others. Moreover some similar sub-zones have been recognised by M. Delatour in the Gault of Brienne (Aube).

A sub-zone may be defined as a portion of a zone which is characterised by one or more peculiar species, but there is not necessarily a succession of such sub-zones. Thus the zone of *Ammonites varians* in the Lower Chalk has at its base the sub-zone of *Stauronema Carteri*, but no other sub-zone has as yet been established in that zone.

Mr. S. S. Buckman is of opinion that still more minute sub-division of the zone is necessary, and he has proposed the term *hemera* for "the acme of development of one or more species," or, as it might be rendered, the particular horizon at which a certain species occurs or is most abundant. He says,[1] "Successive 'hemeræ' should mark the smallest consecutive divisions which the sequence of different species enables us to separate in the maximum developments of strata.[1] In attenuated strata the

[1] Quart. Journ. Geol. Soc., Vol. xlix. p. 481 (1893).

deposits belonging to successive hemeræ may not be absolutely distinguishable, yet the presence of successive hemeræ may be recognised by their index-species or some known contemporary, and reference to the maximum developments of strata will explain that the hemeræ were not contemporaneous but consecutive." On a later page (518) he explains this further by showing that if two species occur together in one thin band of rock, and if this band expands into a greater thickness elsewhere, it will generally be found that the one species occurs in the lower part and the other in the upper part of the bed.

Such observations are interesting and important in the study of a special district, but it has yet to be proved that the succession of fossil species is everywhere the same. Mr. Buckman, however, does not seem to consider that a given species cannot possibly have appeared everywhere at the same time, and that even in the same province or basin of deposition the order in which species arrived at different localities must often have been different. Suppose one species were entering an area from the east and another from the west, there would necessarily be a line on one side of which the order of appearance would be the reverse of that on the other side; so that starting from a point on this line we should find the superposition in one direction to be $\frac{A}{B}$ and in another direction $\frac{B}{A}$.[2]

It must be remembered, too, that some species go with special kinds of sediment, and that by a change of local conditions the successional order of species may be changed. Dr. J. W. Gregory has mentioned an instance of this; he says,[3] "The slightest variations produced by age may be completely overshadowed by differences due to altered circumstances, and hence the evidence of palæontology must be accepted with considerable caution. Thus in Malta the calcareous marls with fish teeth, etc., occur near the base of the series, and the great *Clypeaster* beds above; but in Corsica the succession is reversed."

The above criticism is only directed against the assumption that the hemera is co-extensive with the zone and that the sequence of hemeræ must always be the same. In certain formations like the Inferior Oolite, where fossils are locally abundant and many species of Ammonites occur, it may be useful to establish both sub-zones and hemeræ, provided that they are not expected to be traceable over large tracts of country; but in the Upper Cretaceous rocks of Britain and in the present state of our knowledge no more minute division than a sub-zone is necessary or desirable.

The Limits of Zones.

The limits of a zone may be definite or indefinite. Where sedimentation has been continuous and fairly rapid the limits of

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[1] Mr. Buckman says that his hemeræ are not to be regarded as subdivisions of a zone, but it is difficult to understand his own explanation of them in any other sense.

[2] See also W. T. Blanford, Address to Geol. Soc. 1889; Quart. Journ. Geol. Soc. Vol. lv. (Proc.) p. 72.

[3] Trans. Royal Soc. Edin., Vol. xxxvi. p. 633.

the zones will naturally be indefinite; some of the characteristic species of one zone may survive into the overlying zone, and others which are characteristic of the latter may make their first appearance in the former. Thus in many cases it is impossible to say exactly where the one zone ends and the other begins, and though by careful collecting one may fix it with fair certainty in one section, one cannot be certain of taking exactly the same plane of separation in another quarry or cliff which is a few miles away from the first. Thus where a zone is complete its limits are indefinite, but the succession of zones will be the same in both places.

Where a zone has definite limits it is generally because sedimentation ceased for a time, and in many cases because an erosive current swept away some of the sediment which had previously been accumulated, thus destroying the continuity of the record and producing what is called a "surface of contemporaneous erosion." Even if the current was only strong enough to prevent the accumulation of sediment, it causes a break in the record, because for a time there is no embedment and preservation of organic remains. In this way, therefore, a zone or a sub-zone may die out when traced in a certain direction.

Thus in South Wiltshire there is a complete passage from the zone of *Pecten asper* and *Cardiaster fossarius* to that of *Ammonites varians*, the latter commencing with the sub-zone of *Stauronema Carteri;* but in Dorset this sub-zone is absent and a higher part of the zone of *Am. varians* rests on an eroded surface of the *Pecten asper* zone.

Correlation of Zones.

When a succession of zones has been well established in one locality, say in a clear and continuous cliff section, it is generally easy to follow the outcrops of the zones inland, provided the rocks are sufficiently fossiliferous and provided there is a sufficiency of exposures.

Again it is seldom difficult to identify the zones of one cliff section or good exposure with those in another such section ten or twenty miles away, provided the beds are of similar lithic character and were deposited in the same marine province or area of sedimentation.

When, however, we have to deal with the deposits of a more distant area, either in the same country or in another country, and with beds of a different mineral character, the correlation of zones and sub-zones becomes more difficult. The succession, which was complete in the first locality, may be incomplete in the other, and we shall then have to determine what zones or parts of zones are present and what are absent. There are sure to be a certain number of species, and often a large number occurring as more or less common fossils in the distant area, which did not exist in the locality first investigated. In point of fact the local conditions may have been so different that the facies of each zonal fauna is different, and though a similar succession of life-

forms may be apparent, yet it will not be easy to correlate the two successions zone by zone.

In such a case as this it will be found necessary to rely more on the evidence of the Cephalopoda than on that of any other class of fossil remains, because they appear to have been more independent of sedimentary conditions, so that each species had a wider and more continuous geographical extension at any one epoch of time; and because the lifetime of each species was generally short, so that their vertical range is generally less than that of other contemporaneous organisms.

The Gasteropoda, Lamellibranchiata, Brachiopoda, Polyzoa, Echinoderms and Sponges are all dwellers on the floor of the sea, and as such are dependent on suitable local conditions of habitat, food and depth of water. Moreover individual species belonging to these classes were often long-lived, and often have a considerable vertical range; for though they may die out and disappear in one area under stress of unsuitable conditions, their free swimming embryos could find suitable environment elsewhere, and consequently could, if not displaced by another species, survive to a later period of time.

We see, therefore, that the doctrine of the identification of

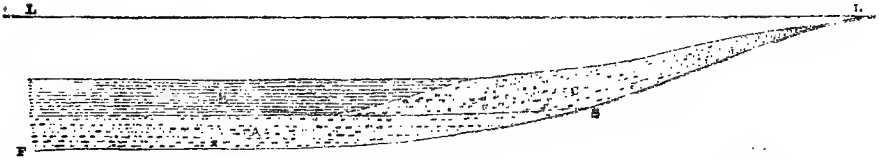

FIG. 8.—*Diagram to Show Method of Accumulation of Sedimentary Deposits.*

zones by the presence of the same species has its limitations. Hence the geologist who is working out the zones of any series of rocks must not rely too implicitly upon the occurrence of any one species, nor on the presence of several species if they belong to the classes above mentioned. He must remember that their presence may be due not to synchronism of deposit but to similarity of environment. In other words, the fossils must not be made the basis for conclusions, apart from a full consideration of the stratigraphical evidence, or they will prove false guides, and will lead the observer to erroneous results.

Thus if he is dealing with a set of deposits which overlap one another and have evidently been formed during the progress of a great subsidence, he must be prepared to find cases where the same species characterise different zones. For example, deposits formed in an early part of the period may be characterised by certain species of *Cardium, Pecten, Rhynchonella, Terebratula, Epiaster or Pseudodiadema,* and above the beds in which these species occur he may find another set characterised by a different specific assemblage, because the species of the lower zone could not accommodate themselves to the changed conditions, so they migrated, and their place was taken by another assemblage. In

another part of the country, however, he may find deposits containing many of the lower zone species mingled with some of those in the higher zone, and the observer may be misled into supposing that he has found a representative of the lower zone, whereas the deposit is really a shallow-water representative of the higher zone.

Such a case is indicated diagrammatically in Fig. 8, where the curved line F S L represents the slope of a sea floor. A is a deposit formed when the sea level was not far above the point S, and B C are deposits formed when the sea level was along the line L L. During the formation of A a certain assemblage of animals existed, but as the water deepened many of these migrated landward and survived to become embedded in the deposit C; this deposit C being formed during the same time that B was accumulated over A. In this case the fauna of C may bear a general resemblance to that of A, but if the Cephalopods are selected alone for comparison it will probably be found that those of C are the same as those in B, and are different from the species occurring in A.

CHAPTER IV.

GENERAL ACCOUNT OF THE GAULT AND UPPER GREENSAND (SELBORNIAN).

Relation to Underlying Strata.

Where the Gault is underlain by Lower Cretaceous deposits, there is generally more or less of a passage from one to the other, and this has led to some difference of opinion as to the exact horizon which should be taken as the base of the Gault in certain districts.

Towards the west, however, the Gault overlaps the Lower Cretaceous series, and where this overlap occurs there is, of course, no difficulty in determining the base-line of the Gault or of its sandy representative in the so-called Upper Greensand. Such is the case in Dorset and Devon; the Gault has been found to overlap the Lower Greensand about half a mile west of Lulworth in South Dorset, and near the village of Okeford Fitzpaine in North Dorset. In South Dorset it rests first on the Wealden, then on the Purbeck and Portland Beds, and thence the combined Gault and Greensand pass successively across the members of the Jurassic System, till they rest on the Lower Lias near Lyme Regis, and on the Trias and Permian in Devonshire.

There is a similar overlap in South Wilts and North Dorset, but along this line a thin and irregular representative of the Lower Greensand accompanies the Gault across the outcrops of the Purbeck and Portland Beds in the Vale of Wardour and on to the Kimeridge Clay in Dorset, till it is overlapped as above mentioned near Okeford Fitzpaine, and the Gault thence passes across the Kimeridge Clay on to older members of the Jurassic series, till it runs out or is lost as a separate argillaceous deposit.

The same is the case in Yorkshire; at Speeton there is a passage from the highest member of the Lower Cretaceous series into the grey and red marls which represent the Gault, but as the beds are traced westward, the "Red Chalk" is found to overlap the Speeton Clay so as to rest first on the Kimeridge Clay, then the Corallian, and finally on the Oxford Clay. In all probability this overstep was continued westward, and if the Cretaceous Rocks had not been entirely removed from the western parts of Yorkshire we should doubtless have found the Red Chalk passing transgressively across all the members of the Jurassic System and also across the Triassic and Permian strata, till they came to rest on the Carboniferous rocks of the Pennine Chain.

In this chapter we shall show that the clays, marls, sands, and sandstones which make up the Selbornian stage fall naturally into three groups or substages: 1, Lower Gault; 2, Upper Gault and Devizes Beds; 3, Warminster Beds.

The Zones comprised in the Lower Gault.

It has been already mentioned that some difference of opinion, exists with regard to the horizon which should be taken as the plane of separation between the Gault and the Lower Greensand; in other words, it has not yet been settled what bed should be regarded as the base of the Gault in those places where the sequence is most complete.

It has been customary in England to regard the Gault as commencing with clayey beds containing *Ammonites interruptus* and to refer all beds below this horizon to the Lower Greensand. In France, however, the sands containing *Ammonites mammillatus*[1] which underlie the clays with *A. interruptus* have always been included in the Gault or Albian of d'Orbigny.

Zone of Ammonites mammillatus.

The existence of the zone of *Am. mammillatus* at Folkestone, as well as at Wissant on the opposite coast of France, was first pointed out by Mons. A. Gaudry in 1859.[2] In 1875. Prof. Barrois[3] claimed the whole of the Folkestone Beds as the equivalent of this zone, but in a later memoir[4] he relinquished this view and limited the zone to the bed described by Mr. F. G. H. Price in the same year as the highest member of the Folkestone Beds.[5]

Mr. Price, writing in 1879,[6] could not accept the view that this bed should be detached from the Folkestone Beds and regarded as part of the Gault. On the other hand, Dr. J. W. Gregory in 1895[7] supports the view maintained by Prof. Barrois. He says "*Acanthoceras mammillare* does not occur in the Lower Greensand except in this uppermost of the four divisions into which Price has divided the Folkestone Beds. This narrow zone must be included in the Albian and regarded as part of the basement-bed of the Gault."

Finally in 1896 Mr. R. B. Newton, recording the discovery of the zone in Dorset,[8] writes, "Opinions were long divided as to whether the *Ac. mammillatum* zone represented the top of the Lower Greensand (Aptian) or the base of the Gault (Albian). The latter view is that generally adopted now on account of so many species passing up into the true Gault series."

It appears, therefore, that this view has gradually been gaining ground among English geologists, but the beds referable to the

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[1] Usually called *mammillaris*, but Schlotheim's name was orginally written *mammillatus*.

[2] Bull. Soc. Géol. de France, Ser. 2, Vol. xvii. p. 32 (1860).

[3] L'Age des "Folkestone Beds." Bull. Soc. Géol. du Nord, t. iii. p. 23.

[4] Terrain Crétacé des Ardennes. B. S. G. du Nord, t. v. p. 227 (1878)

[5] On the Lower Greensand and Gault of Folkestone, Proc. Geol. Assoc., Vol. iv. p. 139 (1875).

[6] The Gault, a lecture privately published. Taylor and Francis, London.

[7] On a Collection of Fossils from the Lower Greensand of Great Chart in Kent, Geol. Mag., Dec. 4, Vol. ii. p. 97.

[8] On the Identification of the *Acanthoceras mammillatum* and *Hoplites interruptus* zones in Dorset; Geol. Mag., Dec. 4, V. iii. p. 198.

zone of *A. mammillatus* in this country are of small thickness, nowhere more than six feet, and the fauna they contain is not a large one. In France the zone of *Am. mammillatus* has a much fuller development, and consequently the question of whether it should be properly included in the Gault or not should be decided by a study of the French deposits. To form an opinion on this point we have carefully considered the evidence published by Messrs. Ebray, Barrois, Delatour and other French geologists.[1]

From their papers we find that the zone of *Am. mammillatus* can be followed all round the eastern and southern sides of the Paris basin; that it is specially fossiliferous in the Departments of the Ardennes and the Meuse; that from localities in these departments Prof. Barrois records 114 species of Invertebrata and that 62 of these (or more than half) pass up into the Gault clays. The commonest species of Ammonites found in these sands are—*interruptus, Beudanti, mammillatus, raulinianus, cleon, regularis, fissicostatus and milletianus;* and all these except the two last pass up into the overlying clays. In other words, not only is *Am. interruptus* found in the zone of *mammillatus,* but *mammillatus* is a common fossil in the zone of *interruptus.*

From these facts it would appear that French geologists could hardly have done otherwise than to regard the two zones as parts of one and the same stage. They were both included by d'Orbigny in his "étage Albien," and though the stratigraphy has been worked out in much greater detail since his time, the results have only confirmed his view that the Albian should include the *Am. mammillatus* sands. This being so, we are forced to conclude that any beds in England which can be shown to be the stratigraphical equivalent of this French zone of *Am. mammillatus* ought to be included in the same stage as the Gault.

There is no doubt that the six feet of sand below the horizon which has usually been taken as the base of the Gault at Folkestone does belong to the zone in question, and we shall therefore include this in our account of the Gault at that place. It is, however, a curious fact that *Ammonites mammillatus* is not a common fossil in England, having only yet been found at one other locality in Kent, at one place in Surrey, and at another in Dorset; but the zone is believed to occur at other places in spite of the absence of the characteristic fossil. The deposits which may possibly represent it will be described and discussed as we come to them.

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[1] The principal memoirs relating to this question are:—

(1) Ebray, Stratigraphie de l'étage Albien dans les départements de l'Yonne, de l'Aube, de la Haute Marne, &c. Bull. Soc. Géol. de Fr., t. xx. p. 209 (1864.)

(2) Ch. Barrois, Sur le Gault et sur les couches entre lesquelles il est compris dans le bassin de Paris. Ann. Soc. Géol. Nord. t. ii, p. 1 (1875).

(3) Ch. Barrois, Le Gault dans le bassin de Paris. Bull. Soc. Géol. de Fr., Sér. t. iii. p. 707 (1875).

(4) Delatour, Sur le Gault des environs des Brienne (Aube). Bull. Soc. Géol. de Fr. Sér. 3, t.v. p. 22 (1876)

(5) Ch. Barrois, Memoire sur le terrain crétacé des Ardennes. Ann. Soc. Géol. Nord., t. v. p. 227 (1878).

Zone of Ammonites interruptus.

Where the zone of *Am. mammillatus* is absent, and such certainly seems to be the case in some places, this zone forms the base of the Gault, and it frequently has a bed or beds of phosphatic nodules at its base. In other places there is a sandy and pebbly bed at the base and sometimes a layer of brown ferruginous rock. This variable basement-bed is succeeded by clays sometimes very dark grey and close grained, and often micaceous and sometimes sandy. These clays vary in thickness from 10 to 50 feet and generally contain the characteristic *Am. interruptus.* At Folkestone they form Bed 1 of Mr. Price's description, and are there only 10 feet thick. In the Midland counties along the outcrop from N. Wiltshire to Cambridgeshire they vary from 20 to 50 feet, but it is really seldom that they can be distinctly separated from those above, because exposures are few and fossils are not common except at one or two horizons.

Proof has been obtained of the existence of this zone as far west as Okeford Fitzpaine near Sturminster in Dorset, and it probably extends still further into the western part of that county, but there is no proof that it enters into the composition of the Devonshire Greensand.

Zone of Ammonites lautus.

Where the Gault is sufficiently fossiliferous and sufficiently well exposed for the succession of beds to be studied, the upper part of the Lower Gault is found to contain some fossils which do not occur in the lowest beds, and this part may be called the zone of *Ammonites lautus.* At Folkestone it includes Beds 2, 3, 4, 5, 6, and 7 of Price, with a total thickness of about 18 feet (see p. 71). It can be distinguished again near Devizes in Wiltshire. It must also form the greater part of the Lower Gault in the counties of Oxford, Buckingham and Bedford, but exposures are so few and fossils so rare in the clays that *Ammonites lautus* has seldom been found; moreover in this part of England the vertical distribution of the various species of Ammonites seems to be different from that which obtains in the south-eastern counties.

Variations in thickness and lithological character of strata.

It must be understood that the several zones above described can only be definitely recognised in the south of England. At Folkestone still more minute subdivisions have been made out by Mr. De Rance and Mr. F. G. H. Price, and these will be described in the sequel, but we do not suppose that these sub-zones have a wide extension even in the south-east of England.

At Folkestone the Lower Gault as a whole, and including the zone of *Am. mammillatus*, is only 34½ feet thick. In the north-west of Kent and in Surrey it appears to be thicker, but we do not yet know how much of the Gault clay in that region belongs

to the Lower Gault and how much to the Upper. Still further west near Devizes it is about 90 feet thick, and as it is followed northwards it becomes much thicker till in Bucks it is known from borings to be 150 feet thick. In Bedfordshire near Hitchin, if all the Gault there is properly regarded as Lower Gault, it attains a thickness of 200 feet, but from that point northward its thickness diminishes till at Soham in Cambridgeshire it is not more than 90 feet.

When it reappears from below the Fenland in Norfolk it is very much thinner, probably not more than 20 feet near Stoke and West Dereham, and only 7 feet at Roydon. Near Dersingham it disappears as a grey clay and becomes part of the bed which is generally known as Red Chalk (see p. 301).

In the south-west of England it can be traced as a band of clay gradually diminishing in thickness from the Vale of Wardour through Dorset to the neighbourhood of Batcombe, and through the coast sections in the south of that county to White Nothe near Weymouth. It reappears in the extreme south-west of Dorset in the cliff sections of Golden Cap, Stonebarrow and Black Ven, and is also present in the cliffs between Lyme Regis and Axmouth, but as a clay it does not extend beyond that place, though its upper portion or zone of *Ammonites lautus* is probably represented in the basement sands of Whitecliff and Beer Head. There is moreover a small outlying patch or "*sublier*" of dark grey clay and clayey sand at the base of the Greensand in a valley east of Honiton, while the occurrence of some Lower Gault species of Ammonites among the fossils of the Blackdown Greensand suggest that it may also be represented in the Blackdown Hills (see p. 213).

Fossils of the Lower Gault.

The Gault has long been noted for the abundance and beauty of the fossils which it contains, and the cliffs near Folkestone have been a favourite hunting ground for collectors from the beginning of the century. The close and compact nature of the Gault clays has preserved the actual shells from decay, and many of the Cephalopoda still retain the pearly lustre of the original shell. Others are casts in iron pyrites with a brassy lustre which is equally beautiful in its way.

But although fossils are often abundant and well preserved in the Lower Gault they are often fragile, and even when they have been extracted or cut out in a small block of the clay, they require much care and attention if they are to be kept as cabinet specimens. If left to themselves the shells often flake off and break up in drying, while the pyrites casts generally effloresce and split into fragments. In order to secure their preservation they should either be soaked for two or three weeks in a very weak solution of gum arabic mixed with a fourth part of glycerine or sugar, or should be treated with a thin solution of gelatine, the latter process giving the most durable results.[1]

[1] See Dr. H. Woodward in Geol. Mag. vol. iii. p. 11 (1866).

LOWER GAULT FOSSILS.

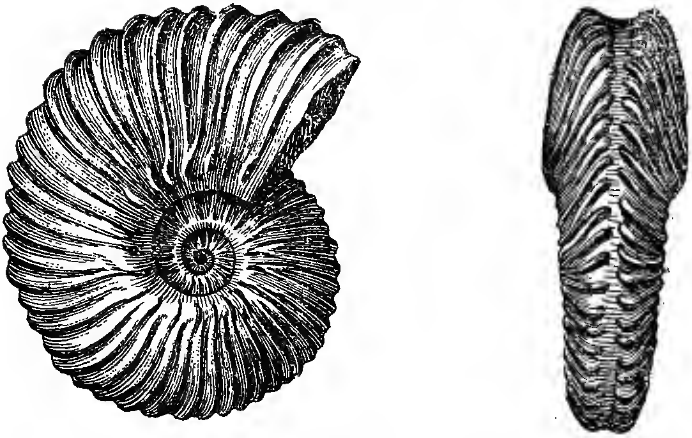

FIG. 9.

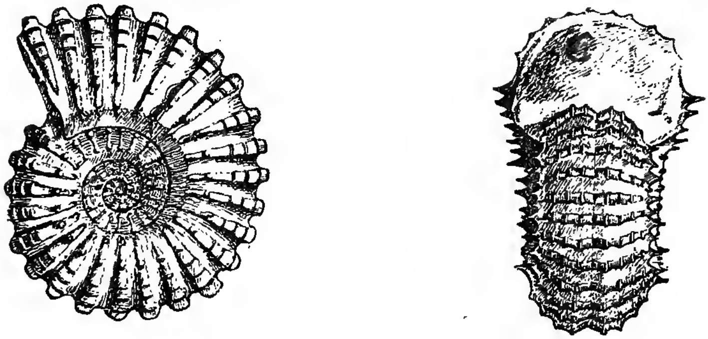

FIG. 10.

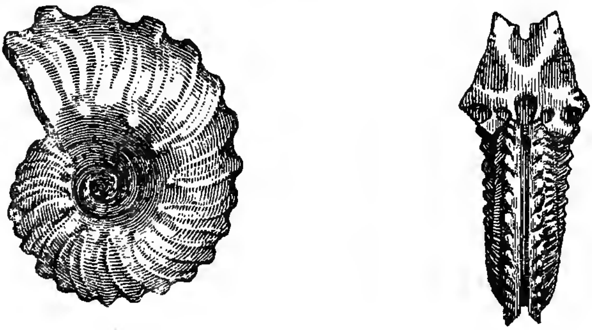

FIG. 11.

Fig. 9. Ammonites interruptus, *Brug.* (after Pictet in Pal. Suisse), reduced to nat. size.

Fig. 10. Ammonites mammillatus, *Schloth.* (after d'Orbigny in Pal. Franç.), reduced to nat. size.

Fig. 11. Ammonites lautus, *Sow.* (after d'Orbigny), nat. size.

The following is a brief review of the fauna of the Lower Gault.

Among REPTILIA the genera *Ichthyosaurus*, *Plesiosaurus* and *Polyptychodon* are represented, and a peculiar Plesiosaur named *Cimoliosaurus constrictus* found by the fossil-collector John Griffith at Folkestone. There are also several species of the flying Reptiles known as *Pterodactyles.*

FISH-REMAINS occur, but not generally in such number or variety as in the upper part of the Gault.

Of CEPHALOPODA the following species are either restricted to the Lower Gault or occur in it more commonly than in higher beds. The letters *c*, *mc*, and *r* in front of the names indicate that the species is *common*, *moderately common*, or *rare* :—

c. Ammonites auritus, *Sow.* (see Fig. 13).
mc. „ benettianus, *Sow.*
mc. „ Beudanti, *Brong.* (see Fig. 14).
r. „ Delaruei, *d'Orb.*
c. „ denarius, *Sow.*
c. „ interruptus, *Brug.* (see Fig. 9).
c. „ lautus *Sow* (see Fig. 11).
mc. „ mammillatus, *Schloth.* (see Fig. 10).
c. „ raulinianus, *d'Orb.*
c. „ splendens, *Sow.* (see Fig. 12).
c. „ tuberculatus, *Sow.*
r. Ancyloceras spinigerum, *Sow.*
mc. „ tuberculatum, *Sow.*
r. Crioceras astierianum, *d'Orb.*
c. Hamites intermedius *Sow.* (= ? attenuatus, *Sow.*)
c. „ compressus, *Sow.*
mc. „ maximus, *Sow.*
r. Helicoceras gracile, *d'Orb.*
mc. „ rotundum, *Sow.*
r. Turrilites elegans, *d'Orb.*
c. Nautilus bouchardianus, *d'Orb.*
c. „ clementinus, *d'Orb.*
c. Belemnites minimus, *Lister* (see Fig. 18).

GASTEROPODA are numerous at certain horizons, and especially in the upper 6 feet of the *Am. lautus* zone at Folkestone. The following are some of the commoner species :—

c. Acmæa tenuicosta, *Sow.*
mc. Actæon affinis, *d'Orb.*
mc. Aporrhais calcarata, *Sow.*
r. „ cingulata, *P & R.*
mc. „ elongata, *Sow.*
c. „ marginata, *Sow.* (and Upper Gault).
c. „ retusa, *Sow.* (Fig. 16).
mc. Avellana inflata, *d'Orb*
mc. „ pulchella, *Price.*

LOWER GAULT FOSSILS.

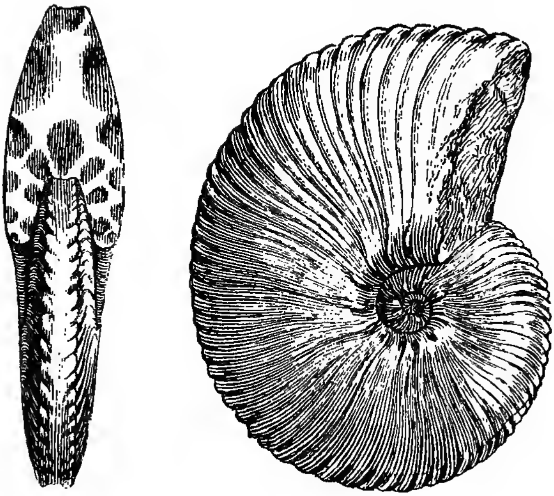

Fig. 12.

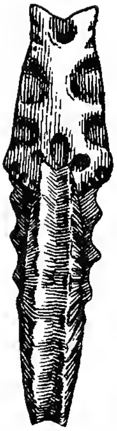

Fig. 13.

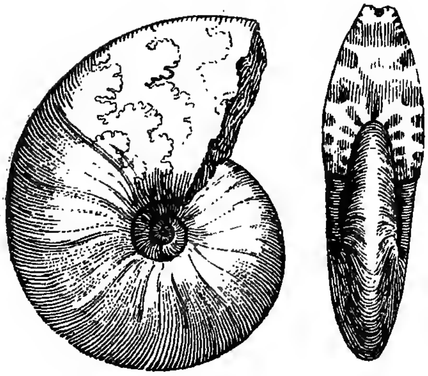

Fig. 14.

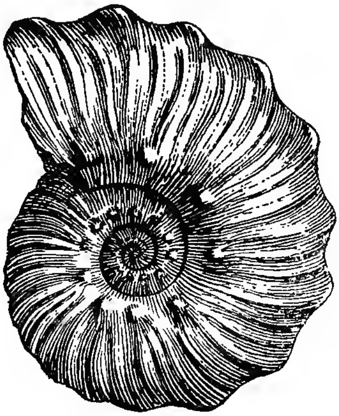

Fig. 13.

Fig. 12. Ammonites splendens, *Sow.*, from a specimen in the Museum of Pract. Geology, nat. size.

Fig. 13. Ammonites auritus, *Sow.* (after d'Orbigny), nat. size.

Fig. 14. Ammonites Beudanti, *Brong.*, from a specimen in the Museum of Pract. Geology, nat. size.

c. Buccinum gaultinum, *d'Orb.*
mc. Cerithium Chavannesi, *Pictet.*
mc. „ subspinosum, *Desh.*
c. „ tectum, *d'Orb.*
c. „ trimonile, *Mich.*
c. Dentalium decussatum, *Sow.* (see Fig. 25).
c. Fusus rusticus, *Sow.*
c. „ Smithi, *Sow.*
c. Natica Genti, *Sow.* (= gaultina, *d'Orb*).
c. „ rotundata, *Sow.*
mc. Phasianella ervyna, *d'Orb.*
c. Rissoina incerta, *d'Orb.*
mc. „ Sowerbyi, *Gard.*
mc. Scalaria clementina, *d'Orb.*
mc. „ dupiniana, *d'Orb.*
c. Solarium conoideum, *Sow.*
c. „ ornatum, *Sow.*
mc. Turritella granulata, *Sow.*
mc. „ vibrayeana, *d'Orb.*

Lamellibranchiata are very numerous both in genera and species, many of them ranging upward into higher beds. Those more especially belonging to the Lower Gault are given below:—

r. Gervillia solenoides, *Defr.*
c. Inoceramus concentricus, *Park.* (see Fig. 15).
c. „ Salomoni, *d'Orb.*
c. Lima parallela, *d'Orb.*, non *Sow.* (Fig. 19).
c. Pecten orbicularis, *Sow.* (ranges upward).
r. Pinna tetragona, *Sow.* (ranges upward).
c. Plicatula pectinoides, *Sow.* (ranges upward). (Fig. 31).
mc. Astarte dupiniana, *d'Orb.*
mc. Corbula elegans, *Sow.*
c. Cardita tenuicosta, *Sow.* (ranges upward).
c. Lucina tenera, *Sow.*
c. Nucula bivirgata, *Fitton.*
mc. „ impressa, *Sow.*
mc. „ Mariæ, *d'Orb.*
c. „ ovata, *Mant.*
c. „ pectinata, *Sow.* (Fig. 17).
mc. Nuculana solea, *d'Orb.*
c. Pleuromya (Panopæa) plicata, *Sow.* (ranges upward).
mc. Pectunculus umbonatus, *Sow.*
r. Tellina phaseolina, *Phil.*
r. Trigonia Fittoni, *Desh.*

Brachiopoda are rarely found in the Lower Gault, so rarely that Mr. Price does not record a single specimen from the Lower Gault of Folkestone except *Terebratula moutoniana* from the *Am. mammillatus* zone. In the counties of Bedford and Bucks, however, *Terebratula biplicata* is not uncommon in the lower phosphate bed formerly worked there.

GAULT FOSSILS.

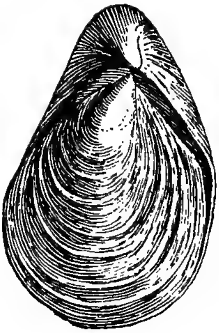

FIG. 15.

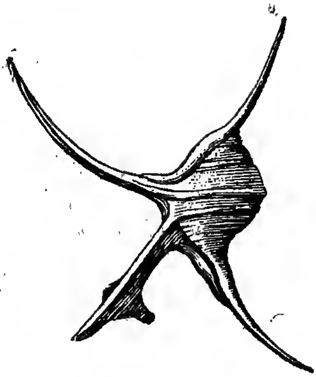

FIG. 16.

FIG. 17.

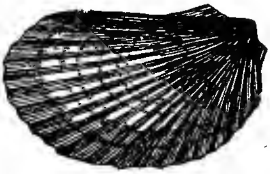

FIG. 19

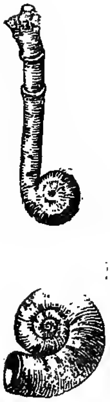

FIG. 20.

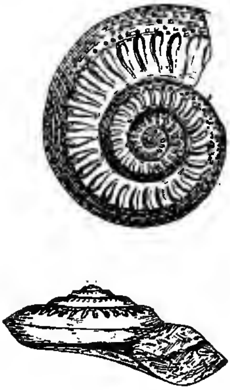

FIG. 21.

Fig. 18.

Fig. 15. Inoceramus concentricus, *Park.* (after Sowerby), nat. size
Fig. 16. Aporrhais retusa, *Sow.* (after Gardner), nat. size.
Fig. 17. Nucula pectinata, *Sow.*, nat. size.
Fig. 18. Belemnites minimus, *Lister* (after d'Orbigny), nat. size.
Fig. 19. Lima parallela, *d'Orb.*, non Sow, nat. size.
Fig. 20. Serpula (Vermicularia) concava, *Sow.*
Fig. 21. Solarium ornatum, *Sow.* (after d'Orbigny), nat. size.

OF CRUSTACEA certain species are very common, but the number of species belonging to the *Decapoda* (ordinary crabs, shrimps and lobsters) is not large. Minute *Entomostraca* are very abundant in some of the beds, but in order to obtain these the material has to be washed and the residue examined with a microscope. The commoner Decapods are:—

mc. Etyus Martini, *Mant.*
r. Homolopsis Edwardsi, *Bell.*
mc. Hoploparia longimana, *Sow.*
c. Necrocarcinus Bechei, *Deslong.*
r. „ Woodwardi, *Bell.*
mc. Palæocorystes Broderipi, *Mant.*
c. „ Stokesi, *Mant.*

All of these except *Pal. Broderipi* range up into the zone of *Am. rostratus.* A few *Cirripedia* occur but none seem to be specially characteristic of the Lower Gault.

ECHINODERMATA are not largely represented; they are creatures which prefer clear water, and the water of the Gault sea was more or less muddy, so that only a few species could exist in it. A Crinoid, *Pentacrinus Fittoni*, is not uncommon, but of Echinids only crushed specimens of *Hemiaster Bailyi* and of an *Echinospatagus* (*asterias*, Forbes= ? *murchisonianus*, Mant.), and two species of *Pseudodiadema* have been recorded.

Of ACTINOZOA a few species of small single cup-corals are not uncommon, but the water was evidently unsuitable for other corals, being both too deep and too muddy. Those commonly found are:—

Bathycyathus Sowerbyi, *Edw. & H.*
Caryophyllia Bowerbanki, *Edw. & H.*
Cyclocyathus Fittoni, *M. Edw.*
Ceratotrochus insignis, *Dunc.*
Trochocyathus conulus, *Phil.*
„ harveyanus, *M. Edw.*

No SPONGES have been recorded from the Lower Gault.

FORAMINIFERA may generally be obtained from samples of the Lower Gault clays. The Folkestone species have been worked out recently by Mr. F. Chapman,[1] and the commonest forms are:—

Anomolina ammonoides, *Rss.*
Cristellaria gaultina, *Berth.*
Globigerina cretacea, *d'Orb.*
Haplophragmium æquale, *Rom.*
„ nonioninoides, *Rss.*
„ Terquemi, *Berth.*
Lagena hispida, *Rss.*

[1] Journ. Roy. Micr. Soc., vols. for 1891 to 1896.

Marginulina æquivoca, *Rss.*
„ striatocostata, *Rss.*
„ Parkerii, *Rss.*
Nodosaria paupercuta, *Rss.*
„ prismatica, *Rss.*
Pulvinulina caracolla, *Rom.*
Sagraina asperula, *Chapm.*

The Upper Gault and Upper Greensand (in part): Merstham or Devizes Beds. *Zone of Ammonites rostratus.*

As stated in Chapter III., it was formerly supposed that the Gault was everywhere, and as a whole, of more ancient date than any part of the Upper Greensand, except the Blackdown Beds in which many geologists recognised that the Gault was partially represented. During the last twenty years, however, it has gradually been ascertained that the greater part of the Folkestone Gault and the greater part of the so-called Upper Greensand are correlative deposits formed at the same time in different parts of the same sea. It is this fact which has compelled us to propose a new name for the stage to which both belong.

The portion of the Selbornian stage which is characterised by *Ammonites rostratus* varies very much in its lithological characters. In Kent, in the eastern part of Sussex, and in Bucks it consists almost entirely of marly clays. In the counties of Surrey, Hants, West Sussex, North Wilts, Berks and Oxford, it consists partly of marl and partly of the grey siliceous stone which is known as Malmstone. In the Isle of Wight there is a varied series of sandy clays, sands and sandstones. In Dorset and Devon the beds are entirely arenaceous. In South Norfolk it is a marly clay of no great thickness, but northward it passes into and becomes part of the red chalky limestone known as the Red Chalk, which extends under the Wash through Lincolnshire and Yorkshire to the sea at Speeton.

Its greatest thickness is probably in the Isle of Wight, where it is 185 feet, and its least is at Hunstanton (less than 2 feet).

No well marked sub-zones have yet been distinguished in this group of beds, except at Folkestone, where the lower 15 or 16 feet are characterised by *Am. varicosus*, and the upper beds (60 feet) by *Am. rostratus* and *Am. Goodhalli.* These two zones are probably traceable through Kent, but have not yet been recognised elsewhere as separable portions of the larger zone or *assise.*

Where the malmstone is developed it forms a natural lithological subdivision, separable from any marls belonging to this group above or below it, but fossils are not generally abundant in it.

Failing any natural subdivision into sub-zones, we shall consequently give a general account of the principal varieties of rock which occur in this portion of the Selbornian stage.

Marly Clays.

Where these occur they appear to consist mainly of very fine argillaceous matter and finely divided carbonate of lime, mixed in varying proportions. Washed residues seldom show any appreciable amount of quartz sand, even in minute grains; mica is sometimes present, but the mass of the siliceous matter is probably silicate of alumina. The proportion of carbonate of lime found by analysis of several samples from different localities varies from 26 to 66 per cent., but this of course includes that which exists in the form of foraminifera and shell-débris, as well as the fine chalky matter which is mixed with the clay.

In North Wiltshire and Berkshire the malmstone passes down into light grey silty marls, which probably contain a certain admixture of silt or fine quartz sand as well as of mica.

The marls of the Upper Gault in fact extend for some distance beneath the northern and eastern portions of the malmstone area, *i.e.*, in the counties of Bucks, Oxford, Berks, and a part of North Wilts, as also in the counties of Surrey and Sussex; but toward the south-west they appear to thin out wedge-wise beneath the thickening mass of sandy deposits, until the latter have entirely taken the place of the marls, and the formation which was wholly marl in Kent has become wholly arenaceous in South Wilts (see diagram, Fig. 51).

Malmstone and Gaize.

We employ the term *Malmstone* to include the rocks known as malm-rock and firestone.

Malmstone may be defined as a fine-grained siliceous rock, the silica of which is either principally of the colloid variety, either in the form of a semigranular ground mass or of scattered microscopic spheroids, or in both forms. Sponge spicules, or the spaces once occupied by them, are always abundant, and seem to have supplied the silica which is now in the globular or semigranular condition. Quartz, mica and glauconite are present, but generally in small quantities. There is always some calcareous matter, but in the purer varieties this does not amount to more than 2 or 3 per cent. Other varieties, however, contain as much as 20 or 25 per cent., and these are called *calcareous malmstones* or *firestones*. These calcareous malmstones are always much heavier and more compact than the more siliceous varieties which have a low specific gravity, are somewhat porous, and feel almost as light as pumice in the hand.

In some localities the malmstone contains concretionary nodules or lumps of bluish chert arranged in layers like flints in the Chalk, but blending so gradually into the surrounding rock mass that they are not easily separable from it.

In some places malmstone passes into a micaceous sandstone in which quartz, mica, and glauconite are the most conspicuous materials, though the microscope shows that sponge spicules and globular silica are still important ingredients. This material is the *Gaize* of French geologists, and the name might be usefully

employed in England for any sandstone of this description. Prof. Ch. Barrois was the first to recognise the identity of the English and French *Gaize*. Describing the zone of *Ammonites rostratus*, he says: "Near Devizes it is in the state of gaize; the gaize of Devizes contains exactly the same fauna as that of the Argonne, and its mineralogical aspect is so similar that on going into the cutting by the station at Devizes, the geologist might imagine that he had suddenly arrived at the station of Vouziers."[1]

The Malmstone, with its associated beds of gaize and firestone occupies a large area in southern England, and its thickness along part of the western outcrop shows that it originally stretched far to the westward over the counties of Oxford, North Wilts and Gloucestershire. Its eastern limits are Westerham in Kent and Amberley in Sussex; its northern limit is near Risborough in Bucks, and toward the south-west it terminates a little south of Shaftesbury. Its greatest thickness is near Wallingford in Berkshire, where it is nearly 100 feet thick, and there can be little doubt that it has a continuous subterranean extension beneath the Chalk and Tertiaries which occupy the area between its western and eastern outcrops.

The Malmstone, in fact, was originally deposited in a huge lenticular mass, and the portion of it which remains, including both the surface and subterranean extension, occupies an area of nearly 4,000 square miles.

Grey, Green, and Yellow Sands.

In the Isle of Wight and in the south-west of England a large portion of the zone or sub-stage of *Ammonites rostratus* consists of fine soft sands. The principal constituent of these sands is quartz in very small even-sized grains; glauconite is always present also in small grains, imparting a grey or greyish-green tint to the sand, but where the beds have been long exposed to the weather the colour becomes yellowish by oxidation of the iron in the glauconite. Mica is generally also a conspicuous ingredient, the lower beds being often very micaceous.

These sandy beds are part of the group of sands which is generally called the Upper Greensand, and where this facies of the Selbornian stage is fully developed, there is generally an upward passage from dark grey argillaceous and highly micaceous silts to pure sands, the proportion of mica gradually decreasing until the material is a mixture of quartz and glauconite only.

The sands of the *Am. rostratus* zone often contain interbedded layers of hard calcareous sandstone, generally thin beds from six to eighteen inches thick, which do not persist for any great distance, but thin out lenticularly in every direction. They are merely portions of the ordinary sand compacted by a cement of crystalline calcite. In some places the calcareous matter is concentrated into large "doggers" or "burr-stones," oval or spheroidal in shape, and varying in diameter from one to three

[1] Ann. Soc. Géol. du Nord, t. ii. p. 50 (1875).

feet. Elsewhere, as near Lyme Regis, the calcareous concretions form large tabular masses three or four feet wide by five or six feet long, and these are locally known as "cowstones."

Siliceous concretions are not of frequent occurrence in these sands, but they do occur in the Blackdown Hills of Devon, and in the Penselwood district near Stourton, on the borders of Somerset and Wiltshire. Those of the Blackdown Sands were largely worked in former days for whet-stones or scythe-stones, and similar stones were raised in Penselwood, where they were called "Penstones."[1]

Fossils of the Upper Gault, Malmstone, &c.

The fauna of the Upper Gault is known principally from the fossils found at two localities, Folkestone and Cambridge. The Upper Gault marls are probably fossiliferous throughout Kent, and are known to be so at Burham and Aylesford near Maidstone, but there are few other good exposures. In the Midland counties (Oxford and Bucks) they seem less fossiliferous, but further north they appear to have contained many fossils, for though the marls themselves have been destroyed by erosion, a large number of their organic remains are preserved in the Cambridge Greensand or "Coprolite Bed"; the phosphatic nodules and fossils of this bed having been derived from the upper part of the Gault.

The fauna of the Malmstone and Gaize is chiefly known from the collections made at and near Devizes. For that of the sands belonging to this zone the most fossiliferous localities are the Undercliff of the Isle of Wight, Black Ven near Lyme Regis, the Blackdown and Haldon Hills in Devon.

The fauna of the Upper Gault marls is not quite the same as that of the sandy members of the group; that is to say, certain species which are common in the one set of deposits are rare or non-existent in the other beds. Such differences, however, are found at the present time between an assemblage of animals obtained from the surface of a mud deposit in deep water and one from a sandy floor in shallower water. The differences, too, are chiefly observable among the Lamellibranchs, which are specially influenced by the nature of bottom deposits. The Cephalopoda are less affected, but are much more abundant in the marls than in the sands.

The following is a list of the commoner and of the specially characteristic species which occur in the beds above described:—

Aves.—A few bones of Birds have been found in the Cambridge nodule bed.

Reptilia.—The bones and teeth of marine Reptiles are very common in the Cambridge nodule-bed, and are not uncommon in the Upper Gault marls, but are rare in the malmstone and sandy beds. The commoner species are *Ichthyosaurus campylodon*,

[1] See H. B. Woodward, "Midland Naturalist," Vol. vi. p. 98, and Rev. H. H. Winwood, Proc. Somerset Arch. and Nat. Hist. Soc., Vol. xv.

Carter; *Polyptychodon interruptus*, Owen; *Cimoliosaurus planus*, Owen; *Cimoliosaurus Bernardi*, Owen; *Rhinochelys pulchriceps*, Owen, and other Chelonians; *Ornithocheirus* (*Pterodactylus*) *Fittoni*, and several other species of the Pterodactyles or flying Reptiles.

PISCES.—The bones and teeth of Fish are also abundant in the Upper Gault and Cambridge Greensand. The Chimæroids are represented by several species of *Edaphodon* and *Ischyodus*. Among Plagiostomi there are species of *Lamna*, *Oxyrhina*, *Scapanorhyncus*, and *Hybodus*, but most of them range up into the Chalk. Of Ganoids, *Anomœodus cretaceus*, *Cœlodus ellipticus*, *Portheus gaultinus*, *Protosphyrœna ferox*, and *Enchodus lewesiensis* may be mentioned.

CEPHALOPODA.—Ammonites are not, on the whole, so abundant in this zone as in the Lower Gault, though certain species are common enough. There are also some peculiarities of local distribution; thus at Folkestone *Am. auritus* was not found by Mr Price above the nodule bed (Bed viii.) which forms the base of the Upper Gault; but in the sands of Devizes and of the Isle of Wight it is a common fossil, and it is also common in the Cambridge nodule-bed. *Am. raulinianus* is also common at Cambridge, and occurs in the Isle of Wight, but is very rare in the Upper Gault of Folkestone. The following is a list of the most characteristic species of Cephalopoda which occur in this portion of the Selbornian stage:—

Ammonites auritus, *Sow.* (see Fig. 13).
„ Goodhalli, *Sow.*
„ planulatus, *Sow.* (var. mayorianus, *d'Orb.*).
„ raulinianus, *d'Orb.*
„ rostratus, *Sow.* (= inflatus, *Sow.*), Fig. 23.
„ Studeri, *Pictet.*
„ varicosus, *Sow.* (see Fig. 22).
Anisoceras (Hamites) armatum, *Sow.*
Scaphites hugardianus, *d'Orb.*
Turrilites Bergeri, *Brong.*
„ catenatus, *d'Orb.*
Nautilus albensis, *d'Orb.*

GASTEROPODA.—These are not abundant, though many species have been recorded from the Upper Gault of Folkestone, the Cambridge nodules, and the Blackdown Beds. Among these the following are the most notable:—

Aporrhais marginata, *Sow.*
„ Parkinsoni, *Mant.*
Murex bilineatus, *Pictet.*
„ calcar, *Sow.*
Natica Genti (=N. gaultina, *d'Orb.*), *Sow.*
Pleurotomaria Gibbsi, *Sow.*
„ Rhodani, *Brong.*
Solarium dentatum, *d'Orb.*
„ ornatum, *Sow.*
Dentalium alatum, *Gard.*

FOSSILS (ZONE OF AM. ROSTRATUS).

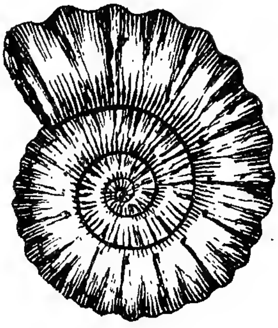

FIG. 22.

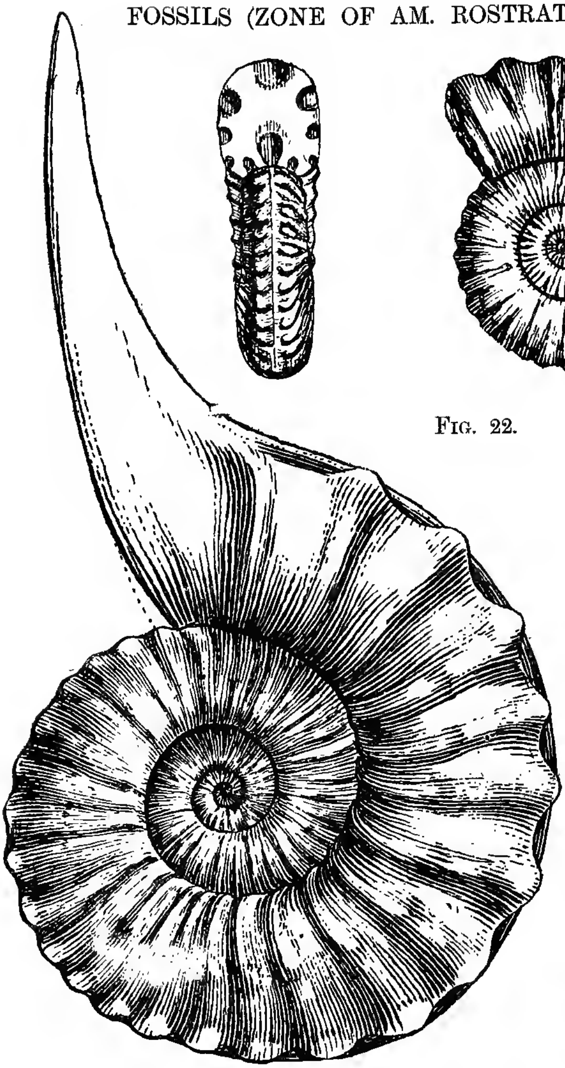

FIG. 23.

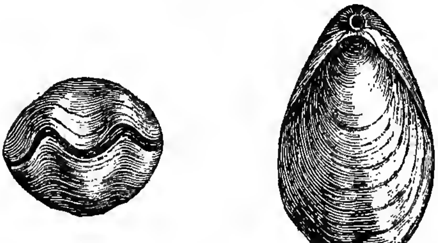

FIG. 24.

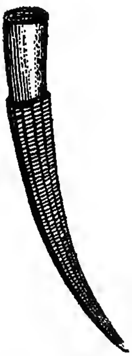

FIG. 25.

Fig. 22. Ammonites varicosus, *Sow.* (nat. size, after d'Orbigny).

Fig. 23. Ammonites rostratus, *Sow.* (reduced from a specimen in the Museum of Practical Geology).

Fig. 24. Terebratula biplicata, *Sow.* (after Davidson) (nat. size).

Fig. 25. Dentalium decussatum, *Sow.* (nat. size).

UPPER GAULT AND MALMSTONE FOSSILS.

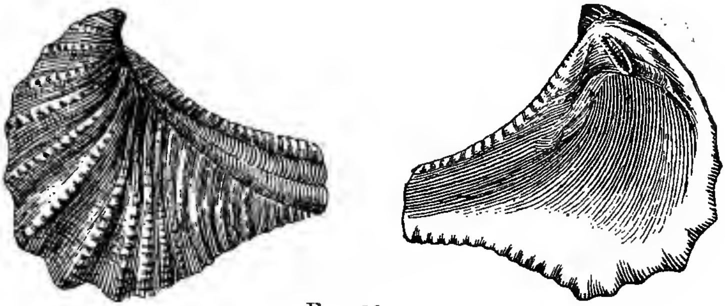

Fig. 26.

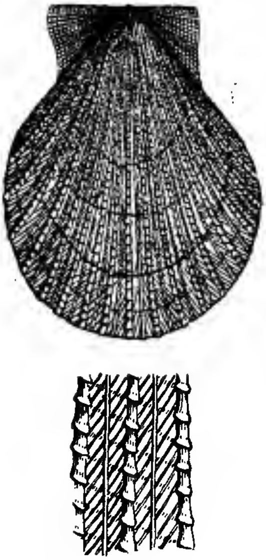

Fig. 27.

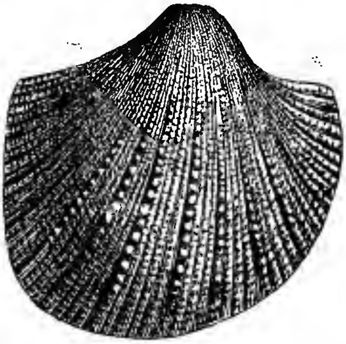

Fig. 28.

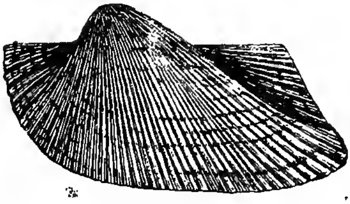

Fig. 29.

Fig. 26. Trigonia aliformis, *Park.* (after Lycett), nat. size, external and internal aspects.

Fig. 27. Pecten Dutemplei, *d'Orb.* (after d'Orbigny), nat. size, with ornament magnified.

Fig. 28. Cardium gentianum, *Sow.* (from a specimen in the Museum of Practical Geology), nat. size.

Fig. 29. Cucullæa carinata, *Sow.* (after d'Orbigny), nat. size.

LAMELLIBRANCHIATA.—Of this class there are many, but some of the commonest species range up from the Lower Gault (see p. 50).

Avicula gryphæoides, *Sow.* (ranges up).
Cardium gentianum, *Sow.*, Fig. 28.
„ hillanum, *Sow.*
Cucullæa carinata *Sow.* (see Fig. 29).
„ glabra *Sow.* (=fibrosa, Sow.) Fig. 33.
Cytherea caperata, *Sow.*
„ plana, *Sow.*
Exogyra conica, *Sow.* (ranges up).
„ rauliniana, *d'Orb.*
Inoceramus sulcatus, *Park.*
Ostrea frons, *Park* (ranges down and up).
„ vesiculosa, *Sow.* (see Fig. 34).
Pleuromya (Panopea) mandibula, *Sow.* (see Fig. 35).
Pecten Dutemplei, *d'Orb.* (= P. Barretti, *Seeley*), Fig. 27.
„ raulinianus, *d'Orb.* (see Fig. 30).
Plicatula pectinoides, *Sow.* (ranges up and down), Fig. 31.
Thetis Sowerbyi, *Ræm* (= major and minor, Sow.)
Trigonia aliformis, *Park* (see Fig. 26).
„ dædalea, *Park.*
„ spinosa, *Park.*
Unicardium ringmeriense, *Mant.*

Of BRACHIOPODA there are very few species, but one is common and widely distributed; this is *Terebratula biplicata*, especially those varieties known as *dutempleana* and *obtusa*. *Kingena lima* is common at Folkestone and Cambridge, *Rhynchonella sulcata* very common at Cambridge, but rare elsewhere.

ANNELIDA.—The only Annelid worthy of notice is the *Serpula* (*Vermicularia*) *concava* (see Fig. 20), which is very abundant in the sands and sandy clays.

CRUSTACEA.—Most of those which occur in the Lower Gault range up into the higher beds of the Gault, and some are also found in the Greensand of the Isle of Wight and Lyme Regis. Besides those mentioned on p. 52, *Diaulax carteriana* and *Glyphæa cretacea* are species only yet obtained from the Upper Gault and the Cambridge nodule bed.

ECHINODERMATA.—The following is a list of the principal species which occur in this part of the formation:—

Cardiaster latissimus, *Ag.*
Cidaris gaultina, *Forbes.*
Echinospatagus murchisonianus, *Mant* (=? asterias, *Forbes*).
Hemiaster minimus ? *Desor* (ranges up).
Hemipneustes Greenovi, *Forbes.*
Pentacrinus Fittoni, *Austen* (ranges from below).
Pseudodiadema ornatum, *Goldf.* (ranges up).
„ tumidum, *Forbes.*
Wiltshirei, *Wright.*

UPPER GAULT AND MALMSTONE FOSSILS.

FIG. 30.

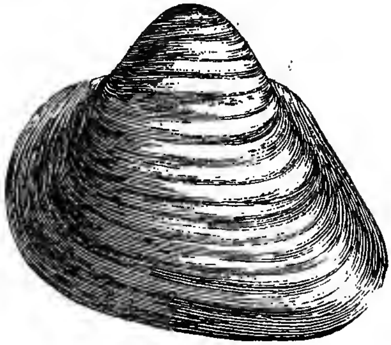

FIG. 33.

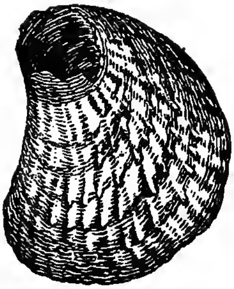

FIG. 31.

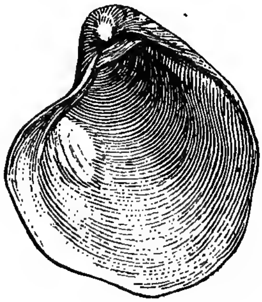

FIG. 34.

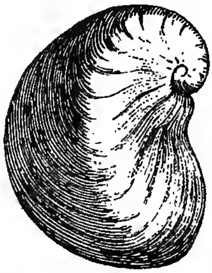

FIG. 32

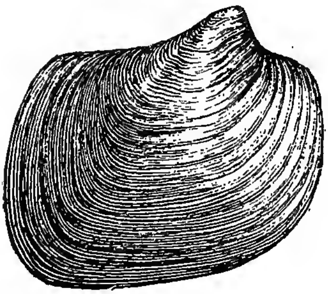

FIG. 35.

Fig. 30. Pecten raulinianus, *d'Orb.* (after d'Orbigny), nat. size.

Fig. 31. Plicatula pectinoides, *Sow.*, nat. size.

Fig. 32. Exogyra conica, *Sow.*, nat. size.

Fig. 33. Cucullæa glabra, *Park.*

Fig. 34. Ostrea vesiculosa, *Sow.* (from a specimen in the Museum of Practical Geology), nat. size.

Fig. 35. Pleuromya (Panopæa) mandibula, *Sow.* (from a specimen in the Museum of Practical Geology), nat. size.

Actinozoa.—The corals which occur in the Lower Gault are also found in the Upper, but in the *Am. rostratus* zone of the Greensand they are rare. A special coral fauna has been found on Great Haldon Hill in Devon, and will be noticed when that locality is described.

Spongida.—Species of *Siphonia* and *Jerea* occur in this zone, and many Ventriculitidæ seem to have lived in the Cambridge area. The Malmstone and Gaize are full of sponge spicules, but have not yielded many perfect sponges.

Warminster Beds, or Zone of *Pecten asper and Cardiaster fossarius.*

Where the Upper Greensand is fully developed, its highest portion generally exhibits some special lithological characters, and contains a special assemblage of fossils, many of which do not occur in the lower part. These beds being well developed near Warminster, have been called the Warminster Beds, and Prof. Barrois in 1876 described them as the zone of *Pecten asper.* We have retained these names, though both require explanation and limitation in order to clear away certain misapprehensions regarding them.

The Warminster Beds, as developed in the neighbourhood of Warminster, and regarded as co-extensive with the zone of *Pecten asper,* include three sets of beds: (1) Green sand and sandstone, (2) fine grey sand, with layers or nodules of chert, (3) light green sand with small calcareous concretions. Near Warminster *Pecten asper* ranges throughout this group of beds, but the fossils which form the well-known Warminster fauna are those of the highest part (No. 3), which is not more than 10 feet thick. A large number of these fossils do not occur in the lower beds (2 and 3), and are not, therefore, characteristic of the group as a whole. Thus, the Ammonites which have been recorded from this zone, both near Warminster and elsewhere, occur only in the topmost bed of it, and are really precursors of the Chalk Marl fauna. No Ammonite or other Cephalopod has yet been found in this zone, which does not range either into the Chalk above or into the beds below.

If therefore one uses the name of Warminster Beds it must be remembered that they include other beds besides those which yield what has been called the fauna of the "Warminster Greensand."

With respect to the term "*zone of Pecten asper,*" the value of the name depends of course upon the range and prevalence of the fossils thus chosen as an index or guide. It was first used by Prof. Barrois in 1874 for certain beds in the eastern part of the Paris basin,[1] and when he found beds containing *Pecten asper* in England and occupying a similar stratigraphical position above the zone of *Ammonites rostratus,* he naturally regarded them as the equivalents of this French zone. Subsequently, however, he

[1] Ann. Soç. Géol. du Nord, t. ii. p. 1 (1875).

came to see that the French zone of *P. asper* was separable into two portions, and he then regarded the lower portion only as the equivalent of the English beds,[1] and the upper part as corresponding with our Chloritic Marl (= his niveau à *Ammonites laticlavius*).

As a matter of fact it is by no means certain that any part of this French zone of *Pecten asper* is the stratigraphical equivalent of that which bears the name in England. It has been ascertained that *Pecten asper* has a much greater upward range than was previously supposed, and that where physical conditions were suitable for its existence, this species continued to flourish long after the close of the Selbornian period.

Thus in the north-west of France it is common in the "craie glauconieuse" of the Cenomanian stage, the equivalent of our Lower Chalk; and near Havre it ranges through 80 or 90 feet of beds above the equivalent of our Chloritic Marl. In England the range of *Pecten asper* is more limited; it occurs in the Chloritic Marl and in the nodule-bed at the base of the Chalk near Chard, and is common in certain abnormal beds of Cenomanian age in Devonshire, but it has never been found in the Chalk Marl proper of the southern, south-eastern or central counties. The mere occurrence of *Pecten asper*, therefore, cannot be regarded as proof that the beds containing it belong to the Upper Greensand. There are, moreover, districts where the undoubted equivalents of the Warminster Beds do not contain *P. asper*, as, for instance, in Devonshire. Yet it is difficult to select another fossil as the index of the zone, because most of the common species range up into the Chloritic Marl. *Cardiaster fossarius* is perhaps, on the whole, the best choice that could be made, but it is not a common fossil, and for the present it may be well to use both fossils as indices.

The beds which form the zone of *Pecten asper* do not extend over such a wide area as those of the underlying zone. They are confined to the south-western and south-central counties from the Isle of Wight to Buckinghamshire. They seem to be represented along the western border of the Wealden area, but are scarcely recognisable in Surrey, and are absent in Kent and in the east of Sussex.

Where fully developed they consist of two sets of green sands and sandstones separated by fine grey silty sands containing nodules of chert. Their maximum thickness may be put at 60 feet, but the chert beds are sometimes absent, and the whole group is sometimes reduced to a thickness of only 10 or 12 feet.

The lowest part of the zone generally consists of glauconitic sand which is rather coarse in grain and is composed of quartz and glauconite grains without any mica. It generally includes layers or dogger-like masses of calcareous sandstone which are simply portions of the sand compacted into sandstone by a cement of crystalline calcite. In the Vale of Wardour the whole of this greensand (10 to 16 feet thick) is thus converted

[1] Ann. Soc. Géol. du Nord, t. v. p. 321 (1879).

into sandstone, which works as a freestone and has been largely quarried for building-stone.

The Chert Beds generally consist of fine grey or greyish-white silty sand full of sponge spicules and containing irregular layers and lumps of chert; beds of fine sand and cherty layers alternating with one another. A lump or nodule of chert consists of an outer portion which is whitish, and often porous, and an inner portion of compact flinty chert. The relative thickness of these two portions varies greatly, some cherts having a thin whitish crust about half-an-inch thick, enclosing a thick flinty mass, while others consist principally of dull white siliceous crust with only a small kernel or kernels of solid chert.

The solid flinty chert varies much in colour; sometimes it is palé grey, sometimes dark grey or black, and in some cases it is coloured yellow, brown, or reddish by the oxides of iron. In thin fragments it is often pellucid and translucent, and is generally hard enough to scratch glass. Sometimes, however, cherts occur in association with coarser quartziferous sand, and then they may include grains of quartz and glauconite. When such cherts are broken the fracture traverses the included grains, and the severed quartz grains show up as glistening crystalline specks.

Above the Chert Beds there is always a bed of green sand, or of calcareous sandstone, before the Chloritic Marl or base of the Chalk is reached. The aspect and mineral condition of this bed differs much in different localities. Sometimes it consists chiefly of fine-grained glauconitic sand, as in the Isle of Wight; sometimes of greenish sand with large quartz grains, and encloses lumps or nodules of whitish calcareous stone, as near Warminster; sometimes it is a hard nodular calcareous sandstone, as in Dorset; and sometimes a compact calcareous sandstone, as in Devonshire.

It generally contains fossils, and *Pecten asper* is generally common in it. At Shute and Rye Hill Farms, near Warminster, it has yielded many fossils, and it is in this bed that some of the Chalk Marl fossils make their first appearance. In Wiltshire and in the Isle of Wight it passes up into the Chloritic Marl; but in Dorset and Devon its surface is waterworn, and clearly marked off from the glauconitic and noduliferous chalk which rests upon it.

Where it is in the condition of sand or soft sandstone it is sometimes 10 feet thick, but the calcareous sandstones of Dorset and Devon are seldom more than 8 feet thick.

Fossils of the Warminster Beds.

VERTEBRATA—Remains of Vertebrate animals are not common in this zone, but the teeth of sharks (*Lamna*, &c.) occur occasionally.

CEPHALOPODA.—These are not common fossils in the Warminster Beds, and have only been found in the stratum which forms the summit of the Upper Greensand in Wiltshire and

FOSSILS OF THE ZONE OF PECTEN ASPER.

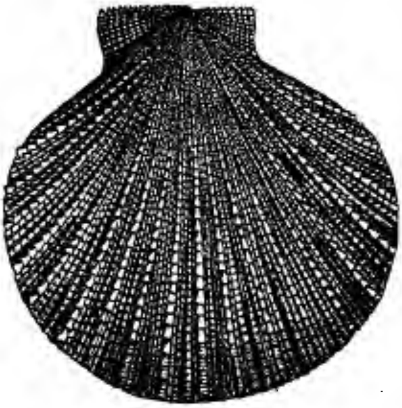

FIG. 37.

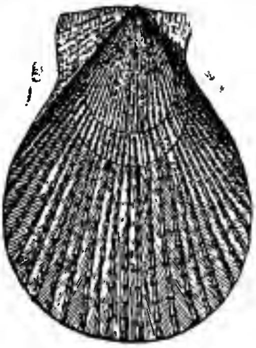

FIG. 38.

FIG. 36.

FIG. 43.

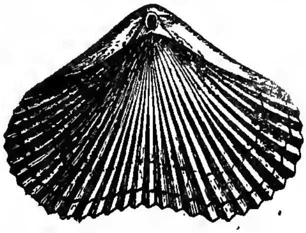

FIG. 41

FIG. 40.

FIG. 39.

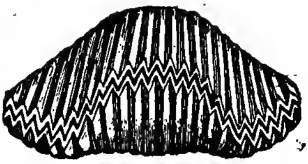

FIG. 42.

Fig. 36. Lima semisulcata, *Nils.*, twice nat. size. Drawn from a Haldon specimen in the Museum at Jermyn Street.
Fig. 37. Pecten asper, *Lam.*, nat. size (after d'Orbigny, Pal. Française).
Fig. 38. Pecten Galliennei, *d'Orb.*, nat. size (from an English specimen).
Fig. 39. Terebratella pectita, *Sow.*, nat. size, large (after Davidson).
Fig. 40. Terebratula ovata, *Sow.*, enlarged (after Davidson).
Fig. 41. Rhynchonella dimidiata, *Sow.*, nat. size, large (after Davidson).
Fig. 42. Rhynchonella dimidiata, front view.
Fig. 43. Rhynchonella grasiana, *d'Orb.*, twice nat. size (after Davidson).

Dorset. *Ammonites varians*, *Am. falcatus* and *Am. Mantelli* are the commoner forms, but some other Chalk species have been found. In North Dorset there is a nodule-bed which contains phosphatised and apparently derived fossils, among which are Ammonites of species belonging to the *Am. rostratus* zone (see p. 57).

Gasteropoda.—These are not abundant, and none of those which have been found are specially characteristic of the zone.

Lamellibranchiata.—These are common, and the following is a list of the species generally to be met with, though some of them range up into the Lower Chalk.

Exogyra digitata, *Sow.*
Lima ornata, *d'Orb.*
„ semiornata, *d'Orb.* (see Fig. 47).
„ semisulcata, *Sow.*
Neithea cometa, *d'Orb.*
„ quadricostata, *Sow.*
Ostrea canaliculata, *Sow.*
Pecten asper, *Lam.* (see Fig. 37).
„ puzosianus, *d'Orb.*
„ Galliennei, *d'Orb.* (see Fig. 38).
„ hispidus, *Goldf.*
Spondylus striatus, *Sow.*

Brachiopoda are also abundent, and the following species frequently occur:—

Rhynchonella dimidiata, *Sow.* (see Figs. 41 and 42).
„ var. convexa, *Sow.*
„ grasiana, *d'Orb.* (see Fig. 43).
Terebratula biplicata, *Sow.* (type)
„ ovata, *Sow.* (see Fig. 40).
Terebratella pectita, *Sow.* (see Fig. 39).
„ Beaumonti *d'Arch.*
Terebrirostra lyra, *Sow.* (rare but characteristic).

Polyzoa are very common in some places, and the following may be mentioned:—

Ceriopora papularia, *d'Orb.*
Entalophora ramosissima, *d'Orb.*
Radiopora (Cellulipora) ornata, *d'Orb.*

Crustacea are not common, but the three Gault species of *Necrocarcinus* range up into the highest greensand near Warminster, and a new species (*N. glaber*, Woodw.) has recently been discovered in the Chert Beds near Maiden Bradley. Besides these the following have been found:—

Cyphonotus incertus, *Carter.*
Hemioon Cunningtoni, *Bell.*
Plagiophthalmus oviformis, *Bell.*
Xanthosia gibbosa, *Bell.*

FOSSILS OF THE ZONE OF PECTEN ASPER.

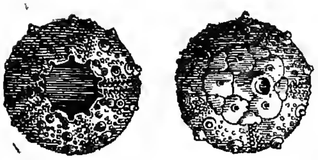

Fig. 44.

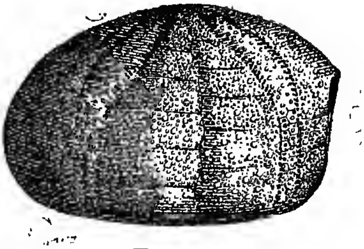

Fig. 46.

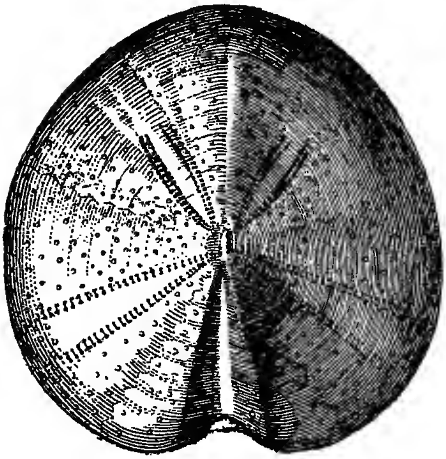

Fig. 45.

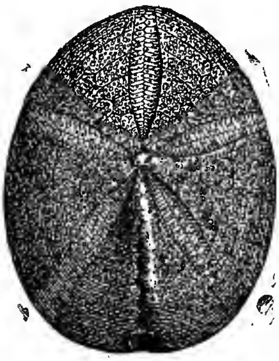

Fig. 46.

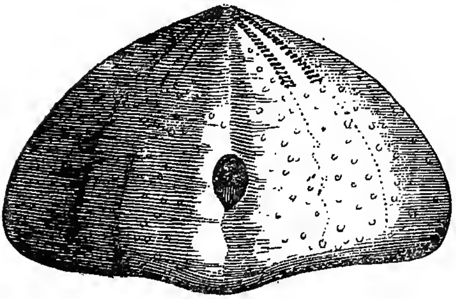

Fig. 45.

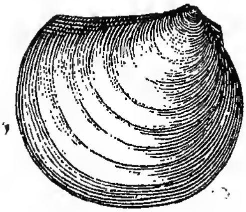

Fig. 47.

Fig. 44. Salenia petalifera, *Desm.*, under and upper sufaces, larger than nat. size (after Wright).

Fig. 45. Cardiaster fossarius, *Benett*, nat. size, viewed from above and from behind (after Wright).

Fig. 46. Catopygus columbarius, *Lam.*, twice nat. size, viewed from the side and from above (after Wright).

Fig. 47. Lima semiornata, *d'Orb.*, nat. size.

Among ANNELIDS there are many species of *Serpula, Ditrupa difformis, Serpula (Vermicularia) concava* (see Fig. 20), in the lower part of the zone, and *Serpula (V.) umbonata* in the highest bed; the latter ranging up into the Chalk.

ECHINODERMATA.—Certain species are very abundant, and more than 30 species have been recorded. The following are the most characteristic:—

Cardiaster fossarius, *Benett*[1] (see Fig. 45).
*Catopygus columbarius, *Lam.* (see Fig. 46).
Cidaris velifera, *Bronn*
Cottaldia Benettiæ, *Kœnig.*
*Discoidea subuculus, *Klein.*
*Echinocyphus difficilis, *Ag.*
*Peltastes clathratus, *Ag.*
* „ umbrella, *Ag.*
*Pseudodiadema Benettiæ, *Forbes.*
„ Michelini, *Ag.*
*Salenia petalifera, *Desm.* (see Fig. 44).
„ gibba, *Ag.*

All those preceded by an asterisk range up into the Chloritic Marl, and most of them into Chalk Marl.

SPONGIDA.—Near Devizes and Warminster a large number of siliceous sponges have been found in these beds. Of these the commonest are:—

Doryderma Benneti, *Hinde.*
Hallirhoa agariciformis, *Benett.*
Jerea Websteri, *Sow.*
Nematinion calyculum, *Hinde.*
Pachypoterion compactum, *Hinde.*
Elasmostoma consobrinum, *d'Orb.*
Tremacystia Orbignyi, *Hinde.*

ACTINOZOA, with the exception of *Micrabacia coronula*, are rare, only three other species of Corals having been recorded.

[1] Miss Etheldred Benett published in 1831 "A Catalogue of the Organic Remains of the County of Wilts," with fine plates of many of the Sponges and Echinoderms that are found in the Upper Greensand near Warminster.

CHAPTER V.

GAULT AND UPPER GREENSAND (SELBORNIAN) IN KENT.

The Folkestone Section.

Between Folkestone Harbour and Copt Point the lower part of the cliff is occupied by the Folkestone Beds (or highest Lower Greensand). These are overlain by the Gault, and nearly the whole of the latter comes in at Copt Point, the summit of which is 130 feet above the sea. Thence the shore sweeps round to Eastwear Bay, and successive beds of Gault come down to the foot of the cliff, but so many slips have taken place along this part of the coast that the order of succession is best ascertained at and near Copt Point.

The Gault of Folkestone has been examined by many geologists, and has long been a favourite hunting-ground for fossils, so that its thickness, subdivisions, and fossil contents have been well investigated. The two best and most detailed descriptions of it are those by Mr. C. E. De Rance in 1868, and by Mr. F. G. H. Price in 1874.

Both these observers divided the Gault into eleven beds of very unequal thickness, which they called zones, because certain species were confined to or specially abundant in each of them. These subdivisions, however, cannot rank as zones in the wider sense in which the term is used in this memoir. For the most part they represent only a local restriction in the vertical range of certain species, and a limitation which is not likely to hold good for any great horizontal distance. *Ammonites auritus*, for instance, is at Folkestone confined to the lower 28 feet of clay, but elsewhere it ranges into beds which represent the higher part of the formation; again, *Inoceramus sulcatus* is at Folkestone confined to a thickness of about 10 feet of clay in the middle of the formation, but elsewhere it occurs at a much lower horizon.

I do not wish, however, to be understood as detracting from the importance and usefulness of the labour expended in the demarcation of these local beds and the careful collection of the fossils obtainable from each. Such work is always useful because the result forms a basis of comparison for other sections, and in this instance it was specially valuable because it brought out the important fact that the Gault of Folkestone was divisible into two portions, a Lower and an Upper, the Lower being characterised by one group of *Ammonites* and the Upper by another group.

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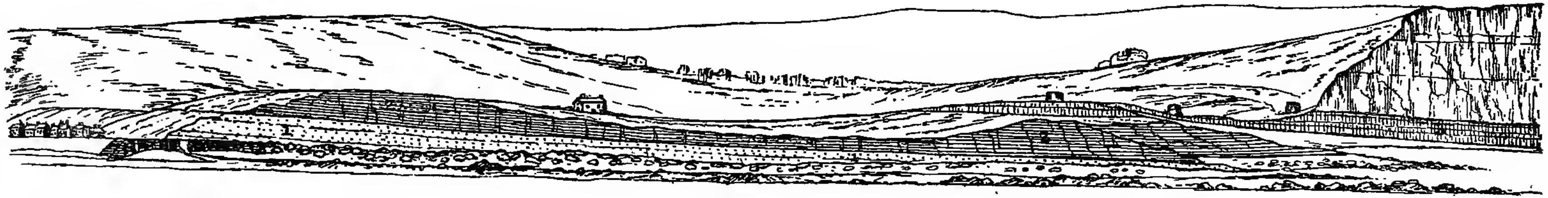
[1] Geol. Mag., Vol. v. p. 163.
[2] Quart. Journ. Geol. Soc., Vol. xxx. p. 342.

Fig. 48. *View of the Folkestone cliffs from the sea* (after Fitton).[1]
Distance about one mile.



Folkestone Harbour. Copt Point.

1. Folkestone Beds, Lower Greensand. 2. Gault. 3. Chalk Marl.

[1] Trans. Geol. Soc., Ser. 2, Vol. iv. Plate VIII.

Fig. 49.

Tabular View of the beds of the Folkestone Gault.

The accompanying diagram is reproduced from that published in Mr Price's paper, and shows the vertical succession of the beds which here compose the Gault.

	Beds.	Characters.	Thickness. Feet	In.	Fossils.
Upper Gault	13	Pale grey and buff-coloured marl	24	0	Few fossils.
	12	Dark glauconitic sand	3	3	Avicula gryphæoides.
	11	Pale bluish-grey marly clay	35	6	Am. rostratus. Am. Goodhalli. Ostrea frons. Pecten raulinianus.
	10	Grey marly clay	5	1	Kingena lima.
	9	Hard marly clay	9	4½	Am. varicosus. Inoceramus sulcatus
Lower Gault	8	Junction bed	0	9½	Am. cristatus
	7	Dark grey clay	6	2	Nucula bivirgata.
	6	Mottled grey clay	1	0	Am. denarius.
	5	Mottled clay	1	6	Am. lautus.
	4	Light grey clay	0	4	Crustacea.
	3	Light buff-coloured clay	4	6	
	2	Very dark clay	4	3	Apor. calcarata. Ancyloceras spinigerum.
	1	Dark clay and glauconitic sand, with nodules at base	10	1	Am. interruptus. Trigonia Fittoni.
	1a	Yellowish sand with phosphatic nodules	6	2	Am. mammillatus.
			112	0	

Mr. De Rance was the first to establish this division of the Gault into two parts, drawing the line between them at a band of phosphatic nodules about 28 feet from that which he took as the base. Mr. Price's more prolonged researches confirmed this division and showed that, out of a total number of 247 species, 124 were confined to the Lower Gault and 57 to the Upper Gault, only 46 species passing from one to the other.

In the following account of the Gault of Folkestone we shall follow Mr. Price in the main, but shall describe it as consisting of 14 beds instead of the 11 shown in his table. Our reasons for increasing the number are as follows.

In the first place, as stated on p. 44, we consider that the base of the Gault should be placed 6 feet lower than the horizon which was taken as such by Mr. Price and most previous observers. In other words, we propose to include in it the zone of *Ammonites mammillatus*. Then again in the Upper Gault Mr. Price grouped together no less than 56 feet in his Bed II. It is quite true that fossils are not abundant in any part of this 56 feet, and that none of them seem to have a specially restricted range, but the bed of glauconitic sand which occurs near the middle of it presents such a marked lithological contrast to the marly clays above and below that we think a subdivision should be made on lithological grounds alone. When Upper Gault is compared with Upper Greensand it is important to remember that even at Folkestone it contains a bed of "greensand."

With regard to the thickness of the Gault at Folkestone we differ slightly from Mr. Price, as apart from the inclusion of the *Am. mammillatus* zone in the Lower Gault, we make the thickness of the Upper Gault amount to 78 feet instead of 71 feet 6 inches. This is because in measuring the upper beds near Martello Tower No. 2, a recent slip was found, the face of which showed 22 feet of clay above the seam of glauconitic sand without reaching the top of the Gault. We therefore assign a thickness of 24 feet to our Bed 13 instead of 17½ feet.

The Lower Gault clays have a thickness of 27 feet 10 inches, and that of the zone of *Am. mammillatus* may be put at 6 feet 2 inches, so that with our grouping the thickness of the Lower Gault comes to 34 feet, and the total thickness of the Folkestone Gault will then be exactly 112 feet.

It will be noticed that although we make fourteen separate beds the numbers only go up to thirteen, since we have entered the lowest as No. 1*a*. This is done in order that the numeration of the higher beds should be identical with that of Mr. Price, as otherwise there would be confusion in comparing our numbers with his.

The following descriptions of the successive "beds" of the Gault at Folkestone have been drawn up from several sources—that of the *Am. mammillatus* zone (Bed 1*a*) has been furnished by my colleague, Mr. G. W. Lamplugh, from his own observations; the account of Beds 1 to 12 has been been derived chiefly from Mr. Price's paper, and from the particulars published by Mr. F.

Chapman in 1891;[1] that of Bed 13 is chiefly from notes taken by Mr. W. Hill, and from Mr. Chapman's examination of samples

Lower Gault.

Bed 1a. (*Zone of Am. mammillatus*). Mr. G. W. Lamplugh contributes the following observations:—

The base of the Gault is very clearly exposed in the cliff at Copt Point, and on the adjoining foreshore on the southern side of East Wear Bay.

The section in the cliff is as follows:—

Gault Bed 1	Gault clay. Lowermost bed of Gault; dark slightly sandy clay, with a few brown nodules. *Am. interruptus.* Band of weathered pyritous nodules, forming a distinct base to the clays, about 6 inches.
Zone of *Am. mammillatus.*	Greensand, coarsish-grained in places, somewhat mixed with dark clay, especially towards the top, 2½ feet. Coarse gritty band, partially indurated into large concretionary masses, with many dark pebble-like phosphatic nodules. *Am. mammillatus*, &c., 1 foot. Incoherent yellowish greensand, 3 feet.
Folkestone Beds	Irregular hummocky rock band of indurated sand, full of markings like worm castings. Similar sands with rock-bands below.

In this section it is evident that the *mammillatus* zone is as closely connected with the mass of the Folkestone beds as it is with the overlying Gault clays. The pyritous band marks off the latter from the sandy series below, and the phosphatised casts of *Am. mammillatus* and its associated fossils lie definitely below the top of the sands. On the foreshore, when not covered by beach material, these nodular bands may be traced from high to low water mark, and owing to a slight roll in the strata their outcrops curve northward, and cover a wide stretch of the shore. In this position the interval between the pyritous band at the base of the clays and the coarsely gritty concretions with *Am. mammillatus* seems to be somewhat less than in the cliff, though they are still distinctly separate.

In the Dover Colliery Shafts, six miles to the eastward, both bands were again recognisable, but the material between them was much more clayey than at Folkestone, and lithologically was considered to form part of the Gault, so that in this section the nodule-bed which yielded *Am. mammillatus* formed the natural base to that division. It should be noted, however, that in these Dover sections the sandy Folkestone beds seemed to have thinned away to a total thickness of only 4 feet, so that their upper portion may be represented only by the layer of nodules at the base of the Gault clays.

The changeable lithological character of these nodular beds is further exemplified by the section at the western side of Folkestone (recorded in the Survey Mem. on the "Geology of

[1] Journ. Roy. Micr. Soc., vol. for 1891, p. 565.

the Weald," p. 147), where three or more distinct bands of phosphatic nodules were found in a matrix passing from clay to sand, so that the exact junction of the Gault with the Folkestone beds was not obvious.

On the foreshore north of Copt Point, where the upper surface of the *Am. mammillatus* band is extensively laid bare, it is seen that the black phosphatic nodules containing the fossils are not uniformly distributed throughout the bed, but are gathered together into little clusters, and that the coarser grains of grit, consisting of well-rounded fragments of quartz, jasper, lydite, etc., up to ¼-inch diameter, are similarly segregated. These clusters seem to have formed centres of induration, so that they are now usually, though not invariably, enclosed in the concretionary masses of grit. The phosphatic casts of fossils are often fragmentary and have an eroded aspect. But as the species they represent are proper to the zone, and are not found in the underlying sands, they cannot be considered as derivative fossils in the ordinary sense of the term. As Mr. Price has pointed out, nodule-beds of this character evidently mark periods of time during which no sediment was deposited, and the currents were strong enough to carry away all except the heavier materials which reached the sea-floor. Under such conditions it would appear that the concretions of phosphate of lime which from time to time accumulated within and around the shells, and other organic remains, slowly decomposing on the sea bottom, were left as casts after the disappearance of the original substance, and were then subjected to the destructive attacks of various forms of marine life, and to the erosive effects of the ocean currents. That the nodules have been formed in a gritty deposit is proved by the abundance of sandy grains within them when examined in microscopical sections. The fact that the phosphatic nodules of the *Am. mammillatus* zone, as in other similar cases, include many species peculiar to them is indicative of the lengthy period required for the formation of the zone.

G. W. LAMPLUGH.

Bed 1.—The bed taken by Messrs. Price and De Rance as the base of the Gault is a layer of pyritic nodules embedded in greenish glauconitic sand, this layer at Copt Point being over a foot in thickness. It is succeeded by a layer of dark green glauconitic sand somewhat clayey and containing two seams of phosphatic nodules and casts, among which *Ammonites interruptus* is a frequent fossil. At Copt Point this seam is only 18 inches thick, but inland near Folkestone it thickens to 3 feet. Many of the fossils in it are sprinkled with small crystals or spicules of selenite, and pieces of wood bored by xylophagous mollusca (Pholadidea, etc.) are common. This green clayey sand passes up rapidly into dark clay, which is traversed by a single seam of nodules near the base, this clay being about 7 feet thick and also containing *Am. interruptus*.

The total thickness of Bed 1 at Copt Point is given by Mr. Price as 10 feet 1 inch. Mr. Price mentions the following fossils as of common occurrence in phosphate: *Ammonites interruptus, Hamites attenuatus, Dentalium decussatum, Nucula pectinata, Trigonia Fittoni, Inoceramus concentricus* and *Palæocorystes Stokesii*. *Belemnites minimus* is also common.

Mr. F. Chapman washed two samples from Bed 1, and we take the following extracts from his description[1]:—

"*Zone* 1. *Specimen a.* From the greensand seam, above the line of iron-pyrites nodules. A dark green glauconitic clay. Residuum after washing, 33 per cent. of glauconitic sand. Many of the glauconite grains are perfectly distinct casts of Foraminifera. The washed material consists mainly of bright green glauconite with a few grains of quartz and chalcedony; also a small shark's tooth. The microzoa are scarce. There are prisms of *Inoceramus* and fragments of other shells, both being tunnelled by the borings of parasitic plants. . . . The finest washings consist of glauconite, angular quartz-grains, and *Anomalina ammonoides*, Reuss.

Zone 1. *Specimen b.* From the level of five feet above the base of the Gault. A greenish grey clay splashed with lighter markings. The proportion of sandy and shelly material remaining after washing is 1¼ per cent. The organisms are all very small The washed material consists of glauconite, prisms of Inoceramus, fragments of Nucula and other testacea, spines of Hemiaster, numerous Ostracoda, Foraminifera and fish-remains. The fine washings consist of glauconite grains, angular quartz-grains and prisms of Inoceramus; *Bolivina textularioides, Globigerina cretacea* and *Anomalina ammonoides* are very common."

Bed 2.—This bed consists of dark grey clay, which looks nearly black when wet, and its total thickness is 4 feet 2 inches. At its base is a layer about one inch thick, containing crushed Ammonites and other fossils with small phosphatic nodules. Three inches above the base is a thin layer in which large crystals of selenite occur, and 12 inches above this is a layer of phosphate nodules. Within this space of 12 inches Mr. Price found three species of mollusca, which did not occur in any other part of the Folkestone Gault; these are *Aporrhais calcarata*, Sow., *Turrilites elegans*, d'Orb., and *Ancyloceras spinigerum*, Sow. Bed 2 also yields a variety of *Ammonites auritus* with much-prolonged dorsal tubercles. The fossils of this bed have their shells well preserved and of a deep rich colour, due probably to the dense compact argillaceous nature of the clay, which has about 70 per cent. of silica and silicates, with only 8·6 of carbonate of lime (see p. 315).

Mr. Chapman washed three samples from this bed for microscopic examination. One from the band of crushed Ammonites yielded a residuum of 12½ per cent. consisting of shelly sand, but microzoa were not common. The finest washings consist of glauconite grains, prisms of *Inoceramus*, and angular quartz. The commonest Foraminifera are the same as in Bed 1. The other two samples came respectively from 9 inches and 1 foot 11 inches above the base; the former yielding a residuum of 4 per cent., the latter 6½ per cent., of shelly sand containing crushed Gastropods, *Inoceramus* prisms, and spines of *Hemiaster*. Ostracoda were common at the higher horizon. The finest washings consisted almoot entirely of glauconite.

[1] Journ. Roy. Micro. Soc., 1891, p. 565.

Bed 3.—The colour of this bed, a light buff or fawn colour, forms a great contrast to that of the bed below, and it is thus easily distinguished. It is known to collectors of fossils as the "crab bed," because *Palæocorystes Stokesi* is especially common in it. Its thickness is 4½ feet, and at its top is a layer of phosphatic nodules and phosphatised fossils in good preservation, many of them retaining the shell and the crabs their carapaces; bones of fishes and of saurians also occur, and a large form of *Inoceramus concentricus.*

Small lenticular masses or layers of clay-ironstone occur here and there in this bed, and a sample of this was analysed by Mr. W. H. Hudleston, and yielded 29·40 per cent. of metallic iron (*see* Chapter xxiii.). The stone is of the same colour as the clay, and contains some of the same fossils, *Corbula elegans* being common in it.

Of this bed Mr. Chapman says, "the clay is of a pale brown or fawn colour, fine in texture, but not close. Residuum 5 per cent. of pale brown dusty sand, with occasional shell-fragments. There are also spines of Hemiaster. . . . . The Foraminifera are fairly common, and the Ostracoda are very abundant: the valves of the latter are often united. The fine washings contain a large proportion of tiny brown granular spherules, a little glauconite, occasional angular grains of quartz and prisms of *Inoceramus.* The little brown spheroidal bodies are composed of carbonate of iron, and appear to be casts of *Anomalina*, as a series may be made out graduating from the infilled shell of the Foraminifer to the roughly spherical cast with its iron-stained umbilical depression. The fine washings on analysis yield 26·61 per cent. of metallic iron in the state of ferrous oxide." The following Foraminifera occur in these washings,—*Textularia pygmæa, Bolivina textilarioides, Globigerina cretacea,* and *Anomalina ammonoides.*

Bed 4.—This bed is only a narrow band four inches in thickness, but it was separated by Mr. Price because he found in it *Am. Delarui*, a peculiar and rather rare form of the *cristatus* group of Ammonites, the members of which are seldom found in the Lower Gault, and because there is a layer of rolled nodules and casts of fossils at the top. We should not ourselves have separated this thin seam, but should have followed Mr. de Rance, uniting it with the overlying Bed 5. We retain it, however, in order to make as little difference as possible between Mr. Price's numeration and ours. Mr. Price observes that remarkably fine specimens of *Dentalium decussatum* occur in this seam, as if the conditions were at this time specially favourable to the growth of this mollusc. Other special fossils are a small species of *Hoploparia, Natica obliqua, Fusus gaultinus,* and a variety of *Am. tuberculatus* with very long spines.

Mr. Chapman describes this layer as "a dark green clay, very fossiliferous. The washed material consists of a brown shelly sand, 1¾ per cent. of the whole, with spines of *Hemiaster*. The Foraminifera are tolerably abundant, and very small. The fine washings consist of glauconite, angular grains of quartz, and innumerable prisms of Inoceramus; also [brown] casts of *Anomalina* like those found in zone 3, though here very rare. The following Foraminifera occur in the washings:—*Lagena lævis* Montagu (one specimen); *Globigerina cretacea,* d'Orb. (frequent); and *Anomalina ammonoides,* Rss. (frequent).

Bed 5.—This is a bed of dark grey clay with light buff-coloured spots and markings. Its thickness is one foot six inches and Mr. Price calls it "the coral bed," from the abundance of the small coral *Trochocyathus conulus*. He also mentions the following species as occurring for the first time in this bed:—

Ammonites lautus.	Phasianella ervyna.
" raulinianus.	Cardita rotundata.
Avellana inflata.	Nucula vibrayeana.
Bellerophina minuta.	Baculites Gaudini.
Solarium conoideum.	

He notes four species as peculiar to this bed, namely:—

Solarium albense.	Funis cancellatus.
" moniliferum.	Astarte dupiniana.

Lumps of fossil resin or copalite are occasionally found at this horizon, and sometimes also pieces of ironstone like that in Bed 3.

Mr. Chapman washed a sample from this bed and found that "the residuum consists of 4½ per cent. of somewhat sandy material with a few shell fragments. The Foraminifera are very abundant, and the larger specimens are frequently filled with pyrites. Ostracoda are common. The fine washings consist of glauconite with numerous distinct casts of Foraminifera, a few angular grains of quartz, Inoceramus prisms, and numerous casts (in carbonate of iron) of Anomalina; also *Textularia pygmæa*, Reuss, (frequent); *Bolivina textularioides*, Rss. (rare); *Globigerina cretacea*, d'Orb. (common); and *Anomalina ammonoides*, Rss. (common)."

Bed 6.—This bed is also of small thickness, about 12 inches, and consists of mottled clay, rather darker than that of Bed 5, with larger mottlings of light grey colour; hence it is known as the "Mottled bed." It is marked off from the succeeding bed by a layer of hard [? calcareous] ragstone about 6 inches thick. *Ammonites denarius* is more common in this bed than in any of the others, and *Turrilites hugardianus* and *Aporrhais histochila* have only been found at this horizon.

Mr. Chapman describes the sample he took from this bed as "a blue grey clay with dark greenish spots and streaks; some of these markings are surrounded by a pyritous stain. The microzoa are very abundant, and *Rotalia spinulifera*, Rss. is the commonest Foraminifer. The washed clay gives a residunm of 7 per cent. which is composed mainly of glauconite and shell fragments. The fine washing consists of glauconite, a few Inoceramus prisms, shell fragments, many casts of *Anomalina*, a few angular grains of quartz, and the following Foraminifera:—*Lagena hispida* (one specimen), *Globigerina cretacea* (very common), and *Anomalina ammonoides* (very common).

Bed 7.—This is a bed of uniform dark grey clay a little over 6 feet thick, lying between the hard rag above mentioned and the layer of phosphate nodules which forms the base of Bed 8. It is very fossiliferous, Mr. Price having obtained no fewer than 67 species from it; of these 33 (or about half) are Gasteropoda, so that it might well be called the Gasteropod bed. *Ammonites*

auritus is very abundant; *Buccinium gaultinum* and *Nucula bivirgata* are common, and the following species were found only in this bed:—*Avellana dupiniana, Cerithium Phillipsi (?). Natica levistriata, Dentalium acuminatum, Aporrhais Parkinsoni,* and *Nucula albensis.*

Of its minuter structure and contents Mr. Chapman gives the following account:—"A dark green clay with a residuum of 6¾ per cent. after washing, consisting of sandy material with iridescent shell fragments. The microzoa are fairly common; *Rotalia spinulifera* is excessively abundant; spines of *Hemiaster* and arm joints of *Pentacrinus* also occur. The fine material consists of glauconite, a few angular quartz-grains, Inoceramus prisms, a very few granular casts of *Anomalina*, aud the following Foraminifera:—*Nodosaria simplex* (one), *Globigerina cretacea* and *Anomalina ammonoides.*

Bed 8.—This is the bed which both Mr. De Rance and Mr. Price have taken as the "junction bed" or horizon of passage between Lower and Upper Gault. It consists of two layers of phosphatic nodules with a seam of mottled grey clay between them, the whole thickness being about 10 inches. The phosphatic fossils found in these nodule-beds are chiefly Lower Gault species, and may have been derived from the destruction and sifting out of a previously deposited bed.

Ammonites Beudanti, Am. selliguinus, Am. brongniartianus, Am. iterianus and *Am. Velledæ* have only been found in this bed; the first is not uncommon, as is also *Am. cristatus*, which ranges into the bed above. Among Gastropods *Murex calcar* and *Scalaria gaultina*, and among Lamellibranchs *Pecten Dutempléi, P. striatocostatus, Trigonia spinosa, Cyprina quadrata* and *Pholas Rhodani* belong specially to this bed, and were not obtained by Mr, Price from other horizons.

Eight species including *Ammonites bouchardianus, Am. cristatus, Am. cœlonotus, Am. varicosus* and *Inoceramus sulcatus* occur for the first time in this bed.

Mr. Chapman's sample of Bed 8 was "a pale-grey clay with an even texture; a residuum after washing of 4¾ per cent. of a dark colour with a few shell-fragments and spines of Hemiaster. The Microzoa are common, with *Rotalia spinulifera* extremely common. The fine washings consist of glauconite, a few angular quartz-grains, prisms of Inoceramus, with *Globigerina cretacea* and *Anomalina ammonoides.* The granular casts of *Anomalina* are absent from this zone."

Upper Gault.

Bed 9.—With this bed begins the Upper Gault or zone of *Ammonites rostratus.* As defined by Mr. Price, it extends from the nodules at the top of Bed 8 up to a nodular layer which is crowded with crushed specimens of *Inoceramus sulcatus;* the thickness being 9 feet 4½ inches. This bed consists of pale grey marly clay in which the silvery impressions of *Inoceramus sulcatus* are very abundant. This species seems to have had a very thin shell which was easily broken and crushed. *Ammonites varicosus* is another fossil which at Folkestone is more abundant in this bed

than in any other, so that locally it may be termed the zone of *Am. varicosus.* Just below the hard nodular seam at the top of this bed, *Am. rostratus* makes its first appearance, and extends thence up to the top of the Gault. *Avicula rauliniana,* and *Scaphites hugardianus* are other fossils which first occur in this bed and range upwards.

Mr. Chapman took a sample at about 3½ feet from the top of Bed 9 and found that it yielded a small residuum, only 2¾ per cent., after washing. This contained many shell-fragments, many Microzoa (especially Bulimines) and spines of *Hemiaster.* The fine washings contain an abundance of granular casts of *Anomalina,* a large quantity of Inoceramus prisms, many glauconite grains, and a very few angular grains of quartz; also the usual species of *Bolivina, Globigerina,* and *Anomalina.*

Bed 10.—This bed has a thickness of 5 feet 1 inch, and consists of rather hard homogeneous pale grey marly clay. In the middle of it at a distance of 2 feet 8 inches above the layer of crushed *Inoceramus sulcatus* there is a seam of phosphatic nodules among which *Plicatula pectinoides* occurs in great abundance and in good preservation. Above this seam the clay is much mottled, and contains associated stems of *Pentacrinus Fittoni,* sometimes in aggregated masses, also bones of Chelonians and Fish, and the eggs of a species of Crocodile. The bed is measured to another seam of nodules 2 feet 5 inches higher up.

Kingena lima is abundant; *Ammonites rostratus* and *Terebratula biplicata* are fairly common, while the following have only been found within its limits:—*Ammonites Studeri, Am. mayorianus, Aporrhais maxima, Cidaris gaultina, Pseudodiadema ornatum,* and *Hinnites Studeri.*

Mr. Chapman took a sample from the lower part of the bed and found a residuum of 8½ per cent., consisting almost entirely of shelly material, with joints of the stems and arms of *Pentacrinus* and two Shark's teeth. Microzoa very abundant. Fine washings consist of Inoceramus prisms, some glauconite, and granular casts of *Anomalina.* Grains of quartz are scarce. *Anomalina ammonoides* is the commonest Foraminifer.

Bed 11.—The base of this bed is the seam of phosphatic nodules indicated by Mr. Price as the base of his Bed 11, and characterised by the prevalence of *Pecten raulinianus,* and as defined by us it is measured up to the base of the "greensand bed." This distance, measured by Mr. Price at Copt Point, was found to be 35 feet 6 inches; in other words, there is here a mass of pale marly clay including one-third of the whole thickness of the Gault which exhibits similar characters and the same species of fossils throughout its extent.

On analysis by Mr. W. H. Hudleston, this marly clay yielded 26·45 per cent. of carbonate of lime, so that it may fairly be termed a marl. Specimens analysed for Mr. Chapman yielded 37·58 and 40·69 per cent. of $CaCO_3$.

This bed is characterised by *Ammonites rostratus* and *Am. Goodhalli,* both of which here attain a large size.

The following fossils appear to be confined within its limits:—

Diaulax carteriana
Ostrea frons.
Pecten raulinianus.
Inoceramus sp. (? Crispi).
Anisoceras (Hamites) armatum.
Turrilites Bergeri.
Crepidula gaultina.

Mr. Chapman washed and examined seven samples of clay from this zone, taken respectively from depths of 55, 50, 45, 40, 35, 30, and 25 feet from the top of the Gault. The lowest yielded the largest residuum (5 per cent.) of greenish-grey sandy and shelly material. "Foraminifera are not very common and rather small. Ostracoda are frequent. The fine washings contain prisms of *Inoceramus*, glauconite, angular grains of quartz (rather scarce), and granular casts of *Anomalina*," and some Foraminifera.

The next two samples (from 50 and 45 feet) yielded small residues (1½ and 3 per cent.). Foraminifera abounded in both, and the fine washings consisted very largely of Globigerina tests; besides these were shell fragments, Inoceramus prisms, but glauconite was rare, and quartz fragments very few. The following were the commonest Foraminifera: *Miliolina venusta*, *Textularia pygmæa*, *Bolivina textilarioides*, *Dentalina communis*, *Globigerina cretacea*, and *Anomalina ammonoides*.

The next three samples yielded very small residues (average 1·3 per cent.). Microzoa are fairly common; the finer washings consist chiefly of Foraminifera and shell fragments, and some Inoceramus prisms, but glauconite grains, Anomalina casts, and quartz grains are very rare. The same Foraminifera are common, together with *Ramulina globulifera*.

The highest sample was taken at a little over four feet from the top of the bed. It yielded a 4¾ per cent. residuum of fine sandy material. "Microzoa are very common. The fine washings consist almost entirely of the shells of Globigerina, with a few glauconite grains, a few angular quartz grains, shell fragments, a very few casts of *Anomalina*, a few prisms of *Inoceramus* fish-remains," and the same species of Foraminifera as in the lower samples.

Bed 12.—This formed part of Mr. Price's Bed 11, but we have separated on account of its marked lithological character. It is a little over three feet thick, and consists of dark green argillaceous greensand, or marly clay full of glauconite grains. When struck with the hammer it gives a bright green streak, due to the fractured grains of glauconite. There is a layer of phosphatic nodules at the base and scattered nodules occur throughout, the nodules being of two kinds, some black, waterworn and irregular, others light-brown or buff-coloured; the former seem to have been derived from some other bed, for two or more of them are often cemented together by the light phosphate, which encloses glauconite grains and seems to have been formed in the bed itself. Some of the nodules seem to have been phosphatised sponges, *Ventriculites*, *Siphonia* and *Jerea*, and others are of the form to which the name *Hylospongia* was given by Prof. Sollas. Other fossils are not abundant, but the following have been found:—

Ichthyosaurus campylodon.
Drepanephorus canaliculatus.
Belemnites minimus.
Ammonites Goodhalli.
" cælonotus.
Aporrhais orbignyana.
Solarium ornatum.
Avicula gryphæoides.
Pecten orbicularis.
Plicatula pectinoides.
" sigillina.
Inoceramus sp.
Trochocyathus conulus.

A sample of this bed examined by Mr. Chapman left a residuum of 30 per cent., consisting of dark green sand with a few shelly particles. "The fine washings consist of a little more than one-half green glauconite grains, nearly all the remainder being beautifully preserved Foraminifera; there are also numerous fish-bones and teeth frequently exhibiting very fine borings of parasitic plants, . . . and angular grains of quartz are more abundant than in the zones previously mentioned." Besides the usual forms of Foraminifera, *Pleurostomella eocæna*, Gümbel, is of frequent occurrence.

Bed 13.—This includes the remainder of the Gault lying between the "greensand" of Bed 12 and that which forms the base of the Cenomanian. Mr. Price measured this portion of the Gault in the cliff south of Martello Tower No. 3, and gives its thickness as 17½ feet, but we think that the mass of "Upper Greensand" to which he measured must have slipped a little downward out of place, as Bed 13 is certainly thicker at other points. In October 1896 Mr. W. Hill found that nearly the whole of the Upper Gault was exposed in a recent slip between Martellos 2 and 3 and there was here 22 feet of Gault actually visible above Bed 12 without any trace of Greensand above, so that the thickness of Bed 13 must be more than 22 feet.

Bed 12 passes into Bed 13, but the glauconite grains rapidly decrease in number, and at a height of 3 feet up in the latter none are seen. At the place above mentioned the lower 13 feet consist of bluish-grey marly clay drying to a paler grey, then there is 3 feet of mottled grey and pale brown clay passing up into a clay of uniform greyish brown or drab colour, seen for 6 feet. The whole of this bed is traversed by numerous cracks and planes of jointing, the sides of which are stained rusty brown.

Fossils are very scarce in Bed 13, but *Ammonites rostratus* and *Am. Goodhalli* have been found, and Mr. Price records a doubtful *Am. varians.*

Mr. Chapman washed a sample taken 5½ feet from the base, which gave a residuum of 2¼ per cent., this consisting of a pale grey sand with numerous fish-remains and coprolites. The fine washings were composed almost entirely of Foraminifera, with a few glauconite grains, many angular quartz grains, fish-bones, and shell fragments. Another sample 6 feet higher up yielded a smaller residuum, only 1 per cent., but of similar material.

Fossils of the Folkestone Gault.

A complete list of the fossils which have been obtained from the Gault of Folkestone would occupy much space. Such a list has been published by Mr. Price, and this is embodied in the general list of fossils at the end of this volume, but a separate list of the Cephalopoda is given on p. 82.

We have given a description of the Folkestone Gault as a whole, because a complete section of it is exposed in the cliffs, and because in our opinion it represents in itself the whole of the Selbornian stage. The marly glauconite sand which overlies it, and which has often been called Upper Greensand, is regarded by us as the basement-bed of the Lower Chalk and will

List of Cephalopoda from the Gault of Folkestone.

—	Lower Gault.							Junc-tion.	Upper Gault.				
	1a.	1.	2.	3.	4 &5	6.	7.	8.	9.	10.	11.	12.	13.
Ammonites auritus, *Sow*	—	×	O	—	—	×	×	×	—	—	—	—	—
„ „ var.	—	—	—	×	×	×	×	—	—	—	—	—	—
„ „ var. with spines	—	×	—	—	—	—	—	—	—	—	—	—	—
„ Beudanti, *Brong.*	—	O	—	—	—	—	—	—	—	—	—	—	—
„ bouchardianus, *d'Orb.*	—	—	—	—	—	—	—	×	×	—	—	—	—
„ brongniartianus, *Pictet*	—	—	—	—	—	—	—	×	—	—	—	—	—
„ Benettianus, *Sow.*	—	×	—	—	—	—	—	—	—	—	—	—	—
„ cœlonotus, *Seeley*	—	—	—	—	—	—	—	×	×	—	—	×	—
„ cornutus, *Pict.*	—	—	—	—	—	×	—	—	×	—	—	—	—
„ „ var.	—	—	—	—	—	×	—	—	—	—	—	—	—
„ cristatus, *de Luc.*	—	—	—	—	—	—	—	×	×	O	—	—	—
„ Delarni, *d'Orb.*	—	—	—	—	×	—	—	—	—	—	—	—	—
„ Deluci, *Brong.*(=Benettiæ)	—	—	—	—	—	—	—	—	—	—	—	—	—
„ denarius, *Sow.*	—	—	×	—	×	×	×	—	×	—	—	—	—
„ Deshayesi, *Leym.*	—	×	O	—	—	—	—	—	—	—	—	—	—
„ fissicostatus, *d'Orb.*	—	—	—	—	—	—	—	×	—	—	—	—	—
„ Goodhalli, *Sow.*	—	—	—	—	—	—	—	—	—	—	×	×	×
„ interruptus, *Brug.*	—	×	—	—	—	—	—	—	—	—	—	—	—
„ iterianus, *d'Orb.*	—	—	—	—	—	—	—	×	—	—	—	—	—
„ lautus, *Sow.*	—	—	—	—	×	×	×	×	—	—	—	—	—
„ mammillatus, *Schloth*	×	—	—	—	—	—	—	—	—	—	—	—	—
„ mayorianus, *d'Orb.*	—	—	—	—	—	—	—	—	—	×	—	—	—
„ planulatus, *Sow.*	—	—	—	—	—	—	—	—	—	×	—	—	—
„ raulinianus, *d'Orb.*	—	—	—	—	×	—	×	—	—	—	—	—	—
„ roissyanus, *d'Orb.*	—	×	—	—	—	—	—	—	—	—	—	—	—
„ rostratus, *Sow.*	—	—	—	—	—	—	—	—	×	×	×	×	—
„ selliguinus, *Brong.*	—	—	—	—	—	—	—	×	—	—	—	—	—
„ splendens, *Sow.*	—	—	×	—	—	—	×	×	—	—	—	—	—
„ Studeri, *Pict.* and *Camp.*	—	—	—	—	—	—	—	—	—	×	—	—	—
„ tuberculatus, *Sow.*	—	—	—	—	×	O	×	×	—	—	—	—	—
„ varians, *Sow.*	—	—	—	—	—	—	—	—	—	—	—	?	—
„ Velledæ, *Mich.*	—	—	—	—	—	—	×	—	—	—	—	—	—
„ varicosus, *Sow.*	—	—	—	—	—	—	—	×	×	×	O	—	—
„ versicostatus, *Mich.*	—	—	—	—	—	—	×	—	—	—	—	—	—
Ancyloceras spinigerum, *Sow.*	—	—	×	—	—	—	—	—	—	—	—	—	—
„ tuberculatum, *Sow.*	—	—	—	—	×	—	—	—	—	—	—	—	—
Anisoceras armatum, *Sow.*	—	—	—	—	—	—	—	—	—	O	×	—	—
Belemnites minimus, *Lister*	—	×	×	—	×	×	×	×	×	—	×	×	—
Baculites Gaudini, *Pict.* and *Camp.*	—	—	—	—	×	×	—	—	—	—	—	—	—
Crioceras astierianum, *d'Orb.*	—	×	—	—	—	—	—	—	—	—	—	—	—
Hamites attenuatus, *Sow* (= ? intermedius)	—	—	—	—	O	O	O	O	O	—	—	—	—
„ compressus, *Sow.*	—	—	—	—	—	—	?	—	—	—	—	—	—
„ elegans, *Park.*	—	—	—	—	—	—	—	—	—	O	—	—	—
„ intermedius, *Sow.*	—	—	—	×	×	×	—	—	—	—	—	—	—
„ maximus, *Sow*	—	—	—	—	—	×	×	—	—	—	—	—	—
„ rotundus, *Sow*	—	×	—	—	—	—	O	—	—	—	—	—	—
„ Sablieri, *d'Orb.*	—	—	—	—	×	—	—	—	—	—	—	—	—
„ virgulatus, *d'Orb*	—	—	—	—	—	—	×	—	—	—	—	—	—
Helicoceras gracilis, *d'Orb.*	—	—	—	—	—	—	—	—	—	—	—	—	—
„ robertianum, *d'Orb.*	—	—	—	—	—	—	—	—	—	—	—	—	—
Nautilus albensis, *d'Orb.*	—	—	—	—	—	—	×	—	O	—	—	—	—
„ bouchardianus, *d'Orb.*	—	×	—	—	—	—	×	—	—	—	—	—	—
„ clementinus, *d'Orb.*	—	×	—	×	×	×	×	×	×	—	—	—	—
„ sp.	—	—	—	—	—	—	—	—	—	×	×	—	—
Ptychoceras adpressum, *Sow.*	—	—	—	—	—	—	—	—	—	×	—	—	—
„ sp.	—	—	—	—	—	—	—	—	—	—	×	—	—
Scaphites hugardianus, *d'Orb.*	—	—	×	—	—	—	—	—	×	×	×	—	—
Turrilites Bergeri, *Brong.*	—	—	—	—	—	—	—	—	—	—	×	—	—
„ catenatus, *d'Orb.*	—	—	—	—	—	—	—	—	—	×	×	—	—
„ elegans, *d'Orb.*	—	—	×	—	—	—	—	—	—	—	—	—	—
„ hugardianus, *d'Orb.*	—	—	—	—	—	×	—	—	—	—	—	—	—
„ sp.	—	—	—	—	—	—	—	—	×	—	×	—	—

× On authority of F. G. H. Price. O on authority of C. E. De Rance.

be described under that head. We have not found anything in Kent, apart from the Upper Gault, which can be regarded as equivalent to any part of the Upper Greensand of more western counties. It is doubtful whether any representative of the Chert Beds or of the green sands containing *Pecten asper*, which form the topmost member of the formation in Wiltshire and Dorset, exists in Kent; but if a representative of these beds is to be found in the succession near Folkestone, we think it will be in the marly clay of Bed 13. We mention this merely as a possibility and because an Ammonite resembling *Am. varians* has been found in this bed, but we think it more probable that there was simply no deposition of sediment going on in the Folkestone area during the time when the highest beds of green sand were being formed in the west.

Inland Exposures.

In describing the inland exposures of the Gault we shall take first those in which Lower Gault is seen and subsequently those which expose the Upper Gault.

Lower Gault.

The base of the Gault has been frequently exposed in temporary excavations near Folkestone, and the phosphatic nodules were at one time largely raised near Cheriton, the bed being worked in the same way as the Cambridge "coprolite bed" and for the same purpose, but it did not pay and has not been worked since 1876.

Mr. Topley has recorded a section (open in 1865) at the west end of the Lees at Folkestone which showed three layers of phosphatic nodules, as below:—

	Ft.	*in.*
Clay with green grains	2	0
Layer of phosphatic nodules, with pieces of wood bored by Mollusca	0	6
Clayey sand with green grains	1	3
Phosphatic nodules and bored wood	0	1
Sand, green grains fewer	1	0
Phosphatic nodules	0	1
Sand as next above, with a nest of phosphatic nodules in one place	3	0
About	8	0

The section seen in the trenches dug for raising the nodules at Cheriton is thus described by Mr. Topley. "The nodules occur in two beds; the lower one, 12 to 15 inches thick, is the junction-bed of the Gault and Lower Greensand; here it is generally dark in colour and always sandy. Separated from this by two feet of clay is another and more variable bed 3 to 6 inches thick. In the clay between these beds and also in that above them scattered nodules occasionally occur."

The basement bed, "sandy clay with phosphatic nodules," was also shown in the railway-cutting half a mile N.E. of Cheriton Church, resting on yellowish-brown sand.

Between Cheriton and Brooke near Wye the outcrop of the Gault is narrow, and there are few brickyards or other exposures. We have not examined this strip of country, presuming that, if good sections did exist, the succession of beds and of species of fossils would be found similar to that of the Folkestone cliffs.

Mr. Topley mentions a pit north of Stanford Church, dug in Gault clay for about 15 feet and showing two layers of phosphatic nodules 18 inches apart, but he does not record any fossils, so we cannot say what horizon was here exposed.

The following notes on brickyard exposures in Kent are by Mr. W. Hill, who examined them in 1897:—

A small opening in the Lower Gault is to be seen at the Brick and Tile Works at Brabourne Lees. The clay is grey mottled with fawn colour; it contains *Am. splendens*, *Am. lautus*, and *Palæocorystes Stokesi*, and is perhaps a continuation of the Bed 3 of Price.

There is another small pit at Nacolt in dark grey clay containing *Am. interruptus*, *Am. lautus*, and *Hamites maximus*.

The first important section west of Folkestone is that at Kennington Brick and Tile Works north of Ashford, and is mentioned by Mr. Topley.[1] These works are situated about ¼ mile west of St. Mary's Church. The section in 1896 was not very clear, but the general succession was:—

Soil	2 feet
Light bluish-grey clay with many light-coloured phosphates, *Inoc. sulcatus*	4 „
Bluish-grey clay with many phosphate nodules	6 to 8 „
Darker grey clay with few phosphate nodules	4 „
A bed of phosphate nodules	3 inches.
Dark-grey clay seen for	6 to 8 ft.

The foreman of the yard said he had seen the base of the clay some 6 or 8 feet below this.

Am. interruptus occurred in the clay said to have been dug from the lowest bed in the section. Besides this ammonite and *Inoc. sulcatus* already mentioned common fossils were *Am. splendens*, *Am. auritus*, *Hamites intermedius*, *Inoceramus concentricus*, *Nucula pectinata*, and *Dentalium decussatum*.

The occurrence of *Am. interruptus* and *Inoc. sulcatus* seems to indicate that both upper and lower Gault are here exposed, and we may perhaps regard the *Inoc. sulcatus* clay as representing Price's Bed 9, though there was no definite nodule bed observed at its base to represent No. 8.

A small pit close to the road belonging to and immediately opposite the Tile Works at Westwell Leacon, gave the following section:—

	Feet.
Bluish-grey clay full of phosphate nodules, locally called "stone"	5
A well-marked nodule bed with many casts of *Inoc. sulcatus*	1
Dark bluish-grey clay with few phosphates	3
A well-marked nodule bed with *Inoc. sulcatus*	1
Brownish-grey clay dug (to water)	3

[1] Geology of the Weald, p. 147 (the locality being given as Goatly's Lees).

The clay was very fossiliferous, and specimens of the following were obtained:—*Am. splendens, lautus, denarius,* and *tuberculatus, Hamites maximus* and *attenuatus, Inoceramus concentricus* and *I. sulcatus, Aporrhais marginata, Nucula pectinata* and *Nucula ovata.*

If the range of *Inoceramus sulcatus* is the same here as at Folkestone this collection would indicate the junction of the Upper and Lower Gault, but as the other fossils were obtained from the floor of the pit, we do not know whether they occur above or below the nodule-bed.

At Tile Lodge Farm, 1½ miles west of Charing, there is a small pit in Lower Gault (*Am. Benettianus*) and an obscure section at Harrietsham seems to expose both Upper and Lower Gault.

The next section worth recording is at Eyhorne Street, Hollingbourne, which is as follows:—

	Ft.	*in.*
Soil - - - - - - - -	2	0
Bluish grey clay with light-coloured phosphates -	4	0
A marked bed of nodules with *Inoc. sulcatus* - -	1	0
Rather dark bluish-grey clay	4	6
Grey-brown clay drying fawn colour, in one place markedly ferruginous, containing lenticular masses of hard stony material of a dull red colour	1	3
Dark grey blue clay seen for -	6	0

The fossils obtained here were *Ammonites interruptus, splendens, lautus* and *auritus, Hamites intermedius, Inoc. sulcatus* and *concentricus, Nucula pectinata,* and *Belemnites minimus.* The *Inoceramus sulcatus* did not occur below the bed of phosphate nodules, and it would seem that here again we have the junction of the Upper and Lower Gault exposed.

The brickyards of Aylesford and Burham near Maidstone seem to be wholly in the Upper Gault, and will be mentioned under that heading. Another fair section in the Lower Gault is to be seen at Messrs. Durtnell's Brick Works about one third of a mile from the Bat and Ball Railway Station at Sevenoaks. The following sequence was taken in 1896:—

	Ft.	*in.*
Soil and rubble - - -	2	6
Bed of nodules with *Inoc. sulcatus* - -	0	6
Greyish blue clay with fawn coloured mottlings, including thin intermittent layers of reddish stone - -	4	0
Dark greyish brown clay mottled with bluish grey passing down to next - - - - - - - - -	5	0
Grey-brown clay (*Palæocorystes Brodcripi*) - -	2	0
Intermittent layers of reddish argillaceous stone. -		
Dark blue-grey Gault seen for - - -	10	0

The base of the grey-brown clay is washed by intermittent layers of reddish stony material, and where this dies out the base of the bed is still streaked by a rusty stain.

The foreman of the yard said "the clay has been proved by boring to be 20 feet deeper than the present floor of the pit." If this is correct the Lower Gault has become slightly thicker than at Folkestone.

The fossils obtained here were *Ammonites interruptus, tuberculatus, splendens,* and *auritus; Inoceramus concentricus* and *I. sulcatus; Hamites compressus, Dentalium decussatum, Palæocorystes Broderipi, Nucula pectinata, Belemnites minimus.*

The last exposure of the Lower Gault in Kent is at Col. Ward's brickyard half a mile north of the church at Westerham. The section must have been once a good one, but is now obscure (1896), and only about five feet of dark grey gault is to be seen. There were many fossils scattered about where a little clay had been recently dug; these included *Ammonites interruptus, Am. benettianus, Am. raulinianus, Hamites intermedius, Inoc. concentricus, Palæocorystes Stokesi.*

Dr. Fitton mentions the following fossils as obtained in a brickyard near Westerham[1]:—

Ammonites dentatus (*i.e.*, interruptus).
" lautus.
" tuberculatus.
Dentalium decussatum.
Inoceramus concentricus.
Nucula pectinata.

Upper Gault.

Excepting the sections already mentioned, which seem to show the base of the Upper Gault, there are no inland exposures of this division between Folkestone and Maidstone.

The total thickness of the Gault, however, increases very greatly in the interval. As already stated, its thickness at Folkestone may be put at 112 feet; borings at Chatham and Frindsbury, north of Maidstone, proved a thickness of between 192 and 193 feet of Gault, three borings differing only to the amount of a foot. "This," as Mr. Whitaker remarks,[2] "tends to show that, as has been the case further west, too small a thickness may have been assigned to the Gault at the outcrop, which has been given as low as 100 feet, and the supposed abnormal thickness at Trottescliff, where the Gault was not bottomed after 183 feet had been passed through, is not so exceptional as has been thought."

This increase of thickness seems chiefly to occur in the Upper Gault, but there seems also to be a slight thickening in the Lower Gault near Maidstone and Sevenoaks, due perhaps to the incoming of beds eroded at Folkestone and represented by Bed 8 of Price.

In the valley of the Medway there are two fine sections of the Upper Gault, one at Aylesford and the other at Burham.

The Aylesford section is familiar to geologists, for it was described so long ago as 1875[3] and has been visited by the Geologists' Association.[4] It is important as showing the junction of the Gault and the Chalk.

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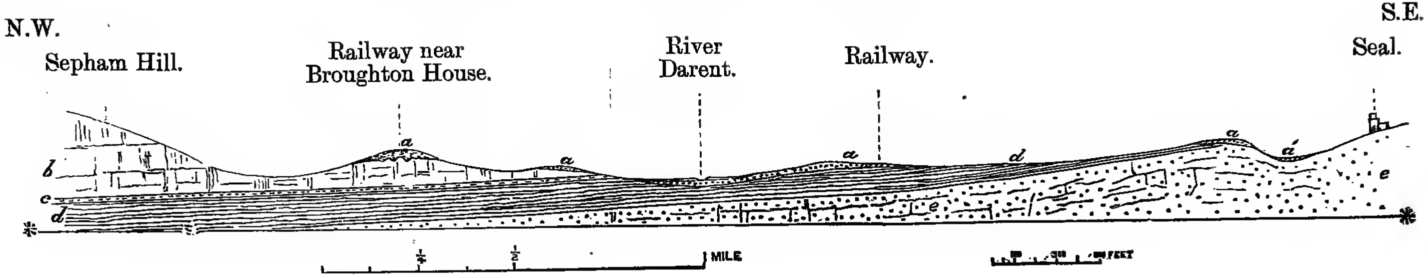
[1] Trans. Geol. Soc., Ser. 2, Vol. iv. p. 152.
[2] Quart. Journ. Geol. Soc., Vol. xlii. p. 38 (1886).
[3] Jukes-Browne, Quart. Journ. Geol. Soc., Vol. xxxi. p. 270.
[4] Proc. Geol. Association, Vol. iv. p. 503.

FIG. 50.—*Section across part of the Darent Valley.* (W. TOPLEY.)[1]



a. River Gravel.
a'. Dry-valley Gravel.
b. Chalk.
c. Upper Greensand.
d. Gault.
e. Lower Greensand.
* * Mean Sea-level.

[1] Geology of the Weald, Fig. 32, p. 190.

The following is the succession of beds seen here by Mr. Hill in 1896, but they are not all visible in one vertical face.

	Soil	1 to 2 feet.
Drift	Sand, fine and coarse gravel	8 to 9 „
Lower Chalk.	Chalk rubble - - -	7 „
	Very glauconitic sandy marl with brown phosphatic nodules - -	1 ft. 3in.
Upper	Light grey clay - - - -	10 to 12 feet.
	Bluish grey clay with *Am. bouchardianus*	15 „
	Bluish grey clay with iron-stained markings	3 „
	Dark-blue grey clay with scattered phosphates	35 to 40 „
		Over 80

The upper part of the Gault is here a light grey when dry and is distinctly calcareous; it changes abruptly to the darker blue-grey clay beneath. The glauconitic bed at the base of the chalk is seen to dip at a slight angle, and cutting through the bed of light coloured Gault finally rests on the bluish clay with *Am. bouchardianus*. The Geologists' Association visited Aylesford in 1876, and in his report Mr. W. H. Hudleston remarks that at the time of the visit the base of the working was about on a level with the *Am. varicosus* zone of Folkestone.

The following fossils were collected by the Geological Survey from the Aylesford pits in 1898:—

----	Up to 6 feet from floor.	From 6 feet to 20 feet up.	From 21 feet to 40 feet up.
Ammonites auritus, *Sow.* -	×	–	–
„ bouchardianus, *d'Orb* -	×	×	×
„ lautus, *Sow.*	×	×	×
„ splendens, *Sow.* -	×	–	–
„ varicosus, *Sow.*	×	–	–
„ sp. -	–	–	×
Ancyloceras tuberculatum ?, *Sow.* -	–	×	× ?
Belemnites minimus, *List.* (& vars)	×	×	×
Hamites sp.	×	–	×
Actæon affinis, *Sow.* -	–	–	×
Aporrhais marginata, *Sow.*	×	–	
Dentalium decussatum, *Sow.*	×	×	
Anomia sp. -	–	–	×
Corbula sp. - -	–	–	×
Inoceramus concentricus, *Park.* -	×	–	–
„ sulcatus, *Park.*	×	–	–
Nucula ovata, *Sow.* -	×	×	–
Cyclocyathus Fittoni, *E. & H.* -	×	–	–
Trochocyathus harveyanus, *E. & H.*	×	–	–

It will be noticed that no *Ammonites rostratus* was found, nor did either of the present writers, who visited the pit at different times, find a specimen; but in the report already mentioned Mr. Hudleston gives a short list of fossils then found,

and among them is *Ammonites inflatus.* This species is evidently so rare at Aylesford (as well as at Burham) that we may be pardoned for suggesting the possibility of some other species having been mistaken for it.

Other species found by ourselves or by Mr. Hudleston are:— *Aporrhais orbignyana, Nucula pectinata, Pentacrinus Fittoni,* and *Trochosmilia sulcata; Ammonites varicosus* and *Inoceramus sulcatus* were also noted as occurring 40 feet above the floor. Thus the fauna of the Gault exposed in this pit is that of the Beds 8, 9, and 10 at Folkestone, and since the surface of the Gault is truncated abruptly and is overlain by sandy marl containing derived phosphatic nodules, it seems very probable that some portion of the Upper Gault has been removed from this district prior to the deposition of the Chalk Marl. There is nothing at Aylesford or at Burham which is in any way comparable to the argillaceous greensand (Bed 12) at Folkestone, and we think that a portion of the Gault representing Beds 13, 12, and most of 11 is here wanting.

The section of the Gault exposed at the Burham Brick and Lime Works, as seen by Mr. W. Hill in 1896, was as follows:—

	Feet.
Soil - - - - -	1½
Pale grey clay containing a few white-coated concretionary lumps - - - - - - - -	6
Light bluish grey clay, drying to lighter grey with fawn-coloured patches or mottlings - - -	27–30
Blue-grey clay passing to a deeper colour at its base -	50–55
In a small pit a little removed from the working face the section was carried lower in dark grey to very glauconitic clay -	6–8

As at Aylesford the change from light coloured clay to the darker is abrupt; it had no relation to moisture contained in the clay and was clearly visible all round the pit.

No nodule-beds or breaks of any kind except colour were observed, the clay presenting a uniform face.

The following fossils were obtained here by the Survey in 1898 from the lower 10 feet of the worked face:—

Belemnites mimimus.
Ancyloceras tuberculatum.
Hamites sp.
Ammonites auritus.
„ bouchardianus.
„ cristatus?
„ denarius.
„ lautus.
„ varicosus.
Actæon affinis.
Aporrhais, cf. Parkinsoni.
Anomia sp.
Arca marullensis.
Inoceramus concentricus.
Nucula bivirgata.
Nuculana vibrayeana.
Pulvinulina caracolla.

Ammonites Beudanti, Nucula pectinata, and *Perna lanceolata* were also obtained from the same horizon by Mr. Hill.

This is substantially the same fauna as that at Aylesford.

A good section of the lower part of the Upper Gault, and possibly some 12 or 15 feet of the Lower Gault, is seen at the brick-

yard a few minutes' walk from the railway station of Dunton Green. The section taken by Mr. Hill in 1896 was as follows:—

Soil - - - -	3 ft.
8. Bluish grey clay mottled with fawn colour, its base marked by a discontinuous concretionary layer - - - - -	7 ft. 6 in.
7. Fawn coloured clay with blue-grey mottlings	1 „ 6 „
6. Greyish brown clay -	4 „
5. Bluish grey clay - -	10-12 ft.
4. A marked line of flat concretionary masses of a reddish brown colour, continuous all round the face - - - -	3-4 in.
3. Bluish grey clay becoming rapidly darker towards the base - -	8 ft.
2. A layer of phosphate nodules -	6 in.
1. Dark grey clay, seen for - - - - - -	12-15 ft.
	About 45 feet.

A number of fossils were collected from different beds at the time the above section was taken, and a few more were obtained by the Survey in 1898. The following list includes those found on both occasions:—

——	Bed 1.	Bed 3.	Bed 5.	Beds 6 and 7.
Belemnites minimus, *List.*	–	x	x	x
Ammonites auritus, *Sow.*	–	x	–	–
„ cristatus, *de Luc.*	–	x	–	–
„ lautus, *Sow.*	–	–	–	x
„ ochetonotus ?, *Seeley*	–	x	–	–
„ raulinianus, *d'Orb.* -	–	x	–	–
„ splendens, *Sow.*	x	x	–	–
„ varicosus, *Sow.*	–	x	–	x
Ancyloceras tuberculatum, *Sow.*	–	–	–	x
Hamites sp.	x	–	x	x
Aporrhais marginata, *Sow.* -	x	–	–	–
Dentalium decussatum, *Sow.*	–	x	–	–
„ alatum, *Gard.*	–	x	–	–
Natica Genti, *Sow.*	–	x	–	–
Solarium ornatum, *Sow.*	–	x	–	–
Cardita tenuicosta, *Sow.* -	–	–	x	–
Inoceramus concentricus, *Park.* -	x	–	–	x
„ sulcatus, *Park.*	–	x	x	–
Nucula ovata, *Sow.*	–	–	–	x
„ pectinata, *Sow.* -	–	x	x	–
Pollicipes unguis, *Sow.* (right tergum)	–	–	–	x
„ rigidus, *Sow.* („ „)	–	–	–	x
Hemiaster sp. - - - - -	x	–	–	–
Pentacrinus Fittoni, *Austen.*	–	–	–	x
Cyclocyathus Fittoni, *E. & H.*	–	x	–	

The bed of phosphatic nodules appears to correspond with Mr. Price's Bed 8 at Folkestone, and the overlying beds may be regarded as belonging to the zone of *Ammonites varicosus.*

Upper Greensand.

In the Memoir on the Geology of the Weald (1875) the sandy glauconitic marl which overlies the Gault at Folkestone was regarded as Upper Greensand, but we agree with Mr. F. G. H. Price (1877) and Dr. Ch. Barrois (1879) in regarding it as Chloritic Marl, in other words as the basement bed of the Chalk. It will therefore be described under that head.

The similar but much thinner bed of greenish sandy marl which is exposed at Aylesford we also consider to be the base of the Chalk, as did Mr. F. Drew, who mapped that district for the Geological Survey.[1] This bed is also found in West Kent, and becomes rather thicker again as it is traced westward.

The true Upper Greensand only commences in the extreme west of the county, probably near Brastead, and the only exposure we were able to find was at the spring head 200 yards west of Court Lodge Farm, 1½ miles N.N.E. of Westerham. Here three feet of greenish glauconitic sandy marl was seen overlying firm grey micaceous and siliceous rock. The rock was greenish grey at the junction with the marl, but passed down into whitish grey rock similar to the malmstone seen in Surrey two miles further west. Its junction with the Gault was obscured. No fossils were found. The glauconitic marl we regard as the base of the Chalk, and the siliceous rock as the setting in of the Malmstone. (See Fig. 50, p. 87.)

It appears, therefore, that the malmstone sets in at the top of the Upper Gault, and, so far as the evidence at this point goes, it might be an entirely separate formation from the Gault, superior to and distinct from the Upper Gault or zone of *Am. rostratus.* We shall see, however, that as it is followed through Surrey and Hants there is good reason to believe that it is developed at the expense of the Upper Gault, and that it is only a special facies of the upper part of the *Am. rostratus* zone, lithologically different from, but stratigraphically equivalent to, the higher calcareous marls of Burham and Aylesford, and the Beds 11, 12, 13 of Folkestone. Consequently if any bed at Folkestone can be called Upper Greensand it is that which occurs in the Gault, our Bed 12.

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[1] Geology of the Weald, by W. Topley, p. 153.

CHAPTER VI.

GAULT AND UPPER GREENSAND (SELBORNIAN) IN SURREY.

General Description.

Entering Surrey from the east the strip of country occupied by the Gault and Upper Greensand follows a direction a little south of west; passing through the northern outskirts of Reigate, a little north of Dorking and south of Guildford, it passes out of the county near Farnham. In consequence of the steep northerly dip, which varies from 5° to 40°, the basset surface or width of outcrop is always a narrow one in Surrey. The zone of *Ammonites mammillatus* is represented only by a few feet of green and yellow or orange-coloured sands with layers of phosphatic nodules varying in thickness from two to six feet. It may be absent altogether in places, but there is no doubt about its occurrence in others. We do not, however, see sufficient reason for including in this zone any of the underlying ferruginous sands.

The succeeding zones of *Ammonites interruptus* and *Am. lautus* which form the Lower Gault, consist of clays which are a continuation of those of West Kent, but little is seen of them, for brickyards are few and the pits in them are shallow. From what can be seen, however, it appears to change its character considerably toward the western part of Surrey, becoming a dark blue pyritous clay in which fossils are very scarce, presenting in this respect a great contrast to the fossiliferous clays of Folkestone.

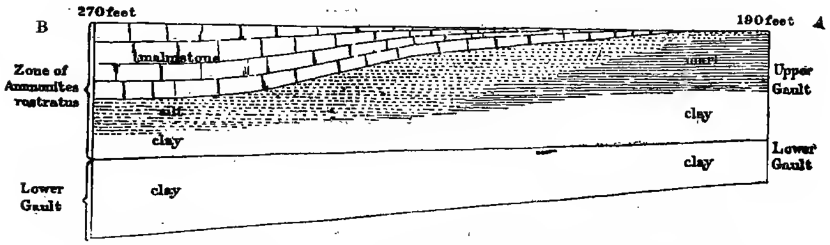
How much of what has been mapped as Gault belongs to the Lower Gault and how much to the Upper Gault (zone of *Ammonites rostratus*) we cannot say; but between the stiff marly clay, which every one would call "Gault," and the beds which are so sandy that every one would call them Greensand, there is a certain thickness of sandy or rather silty marl, for the sandy ingredient is in a very fine state of division. These silty beds are of a dull drab or greyish brown colour; they are well seen near Merstham, where they are only about 20 feet thick, but near Betchworth a thickness of 70 feet of them has been measured, so that they appear to thicken very rapidly westward.

It is not easy to say whether these silty marls thicken independently of the Gault below, or whether there is a lateral change from marly clay to silty marl, and this change gradually affects a greater thickness of beds; but we incline to believe that the latter is the true explanation. There is no doubt that the clays which are called *Gault* become much thinner as they are traced westward; in West Kent, as we have seen, they are nearly 200 feet thick, whilst in West Surrey and in Hants they are

probably not more than 100 feet, and in the same districts the silty marls and sandstones which might be mapped as "Upper Greensand" are from 150 to 170 feet thick.

It has been usual to regard the Malmstone beds as a younger formation than the Upper Gault of Kent, and it is quite possible that it is to some extent a lenticular deposit thickening westward by an increase of siliceous matter derived from an organic source; but when it is considered in connection with these silty marls into which it passes, and in which beds of sandstone sometimes occur, it seems much more likely that it is a case of lateral change. We believe that the upper marly clays of West Kent pass gradually into silty micaceous marl, the change commencing in the highest beds but extending to lower and lower beds as these pass westward; further that the higher silty marls begin to change into soft brownish siliceous earths, in consequence of a larger and larger admixture of siliceous matter derived from the decay of sponges, till at length on the borders of Hampshire they become part of the Malmstone series. Our view is expressed in the diagram, Fig. 51, in which, however, the malmstone is separated from the silts by too definite a line.

FIG. 51 *Diagram to show lateral passage of Gault into Malmstone.*



A. West Kent. *B.* Borders of Surrey and Hants.

The malmstone should have been drawn as passing into the silty beds.

There is, moreover, reason to believe that the westerly thickening is not confined to the Upper Gault, but that the Lower Gault participates in it, for we shall see hereafter that near Devizes, still further west, the whole of the so-called Gault, 90 feet in thickness, belongs to the Lower Gault.

West of Reigate the lower part of what may be called the Merstham Beds consists of a firm silty, slightly glauconitic marl, containing large siliceous concretions, *doggers* or *burrstones,* which are generally arranged in layers. This silty marl passes down into the grey-brown marls below. Above it are thick beds of the soft peculiar kind of sandstone which is so well known as Malm and Firestone; this is a siliceous slightly micaceous rock, containing more organic silica than quartz-sand; but some beds contain much calcareous matter, and these form harder layers of siliceo-calcareous rock. The upper part is generally the most calcareous, and this variety is known as *hearthstone,* the softer and more siliceous varieties being the true *malm* or *firestone.* In the west of the county these beds are probably from 60 to 80 feet thick.

With respect to the zone of *Pecten asper*, it is very difficult to say whether there is any representative of it or not. The whole of the Malm, using this as a general name for the firestone and hearthstone, we regard as belonging to the zone of *Ammonites rostratus;* and there only remains the 8 or 10 feet of greenish-grey sand which lies between the malm and that which we take to be the base of the Chalk Marl. This sand is marly and micaceous, in which respects it differs from the sands of the *Pecten asper* zone in Wilts, Dorset, and the Isle of Wight; it has yielded no fossils except *Lima globosa*, and we do not see any reason for separating it from the underlying rock and putting it into another zone.

If it be argued that the upward passage into the Chalk shows the succession here to be complete, and that a complete succession involves the existence of a zone of *Pecten asper*, we reply that such an argument is fallacious. Nature does not build in perfectly continuous courses, deposition was not continuous everywhere at the same time, and consequently a set of beds containing a special assemblage of fossils may be present in one area but absent in another. As a matter of fact, the sands in question thin out westward, and are absent near Farnham; and as we know that there is no representative of the zone of *Pecten asper* in Kent, we think it unlikely to be present in the intervening tract of country.

With respect to the total thickness of the Selbornian stage in Surrey, it is difficult to form any estimate from the width or slope of the outcrop, because of the northerly dip, which is generally one of 5° or 6° near Merstham and Reigate but increases to 25° and more in the west of the county. Three deep borings in the London basin, however, afford some definite information. That at Streatham Common showed a thickness of 217 feet between the base of the Chalk Marl and the base of the Gault (which there rests directly on Jurassic rocks); of this thickness 28½ feet are grey calcareous sandstone and 188½ are Gault clays. In the Richmond boring the total thickness is almost exactly the same, *i.e.*, 217½ feet, but only 16 feet is assigned to the "Greensand." [1]

At Winkfield near Windsor, which is about 14 miles north of Guildford, the thickness is still greater, being no less than 291 feet, of which 260 feet is Gault marl and clay.[2]

Stratigraphical Details.

Lower Gault.

Mr. Topley[3] records the junction of the Gault with the Lower Greensand in "the road cutting at Stilsum, north of Reigate," again a little east of Reigate Railway Station, and in the road

[1] See "The Geology of London," by W. Whitaker, Mem. Geol. Survey, Vol. ii. pages 215 and 226.
[2] See Whitaker and Jukes-Browne in Quart. Journ. Geol., Vol. l. p. 498.
[3] Geology of the Weald, page 148.

cutting east of Wray Common. Its base is marked by "phos phatic nodules and pieces of Ammonites." In the railway cutting near Wootton the same thing occurs, and in "the cutting north of Abinger Hall, where blue clay is separated by a four-inch layer of brown ironstone from the yellow sand of the Lower Greensand."

A brickfield on the east of the railway between Merstham and Red Hill was visited by the Geologists' Association in May, 1887,[1] and the section then exposed the base of the Gault, the beds seen being described by Messrs. H. W. Monckton and H. A. Mangles as follows:—

Gault	4. ? Clay
	3. Very coarse quartz sand with much glauconite, of a dark greenish grey colour.
	2. Line of small phosphatic nodules.
L.G.S.—	1. Coarse yellow quartz sand.

The beds numbered 2 and 3 probably represent the zone of *Am. mammillatus.*

Mr. Whitaker observed the junction-beds in 1873 in the road a quarter of a mile N.W. of Gomshall railway-station.[2] The beds are dipping north at about 20°, and when his account is thrown into the form of a vertical succession it reads as follows:—

	Feet.
Dark grey sandy clay with phosphatic nodules, some of which show woody structure - -	3 or 4
Clayey greensand with phosphatic nodules in the upper part - - - - -	3
Greensand, lighter coloured and more sandy - -	3
Bright red mottled sandy clay - - - - -	1
Grey clayey sand, mottled with red at the bottom	2
Sharp buff sand.	

Some of these beds probably represent the zone of *Am. mammillatus,* but as no fossils were obtained it is impossible for us to say which. The occurrence of red clay here and elsewhere in the Weald at the base of the Gault is noteworthy in connection with similar beds in Norfolk (see p. 2).

A section showing the junction-beds of the Gault and Lower Greensand is recorded by Messrs.. Boulger and Leighton[3] at Rokefield, between Wootton and Dorking. The succession is described as follows:—

Gault -	1. Gault clay with much glauconite and a few phosphatic nodules.
	2. Sandy blue clay with glauconite.
Folkestone Beds	3. Coarse orange sands with small pebbles and clayey partings.
	4. Red and buff sands to the bottom of the pit.

"The lithological change from sand to clay is abrupt, beds 2 and 3 are junction beds of no great thickness. . . . The Gault is as usual very fossiliferous, the chief forms being *Amm. interruptus* (Brug.)."

[1] *See* Proc. Geol. Assoc., Vol. x. p. 156, and Vol. xiii. p. 77.
[2] In Topley's Geology of the Weald, p. 149.
[3] Proc Geol. Assoc., Vol. xiii. part 1, page 9, 1893.

Lower Gault is seen at Whitedown brickyard, the shallow pit showing a dark grey clay which must be near the base, as Lower Greensand is seen in the railway cutting just beyond; and clay at about the same horizon is seen in the shallow pits at Albury brickyard.

Pits exposing the junction of the Gault and Lower Greensand at Wrecclesham seem to have existed for a long time. They are mentioned by Murchison in 1825, and were fully described by Messrs. Paine and Way in 1848[1] in their excellent paper on the Phosphoric Strata of the Chalk. They say "there are three distinct beds of fossils; the first lies above the thin seam of ironstone; it is about 3 or 4 feet thick, the fossils being intermingled in a soft matrix of sand and clay. . . The position of the second bed is immediately below the iron-sandstone. It consists almost entirely of a conglomerate of fossils in a matrix of sand, which is from 3 to 18 inches thick. The third bed lies about 3 feet lower, and is similar in all respects; occasional fossils are intermingled with the intervening layer of sand." An analysis showed an amount of phosphoric acid equal to 42·48 per cent. of bone earth phosphate. They mention another pit half a mile to the south-west where there is only one bed beneath the iron-sandstone.

"With the more definite fossils are intermixed masses of brownish coloured wood, in most instances bored by teredines."

"On the western side of the parish of Frensham there is a continuation of the fossiliferous strata, skirting the edge of the Alice Holt Forest. The fossils in this locality are chiefly confined to the upper bed at the immediate junction of the sand and Gault clay; they are similar in character to those found at Wrecklesham, but the nodules are generally larger, many of them being of the size of a man's fist."

The section in the pits by Wrecclesham (or Wracklesham) Church was given by Topley as follows, the grouping being my own[2]:—

		Ft.	*in.*
	Blue clay (Gault)	5	0
Zone of Am. mammillatus	Dark sand with phosphatic nodules thinly scattered through it	3	0
	Brown ironstone	0	1½
	Dark sand	1	2
	Phosphatic nodules with pieces of *Ammonites* and other shells	0	4
	Light brown sand	4	6
	Phosphatic nodules, darker than the last	0	4
	Coarse clayey sand with two or three thin bands of clay	5	6
Lower Greensand	Soft brick red sand	0	6
	Light fawn-coloured sand	10	0
		30	5½

[1] Journ. Roy. Agric. Soc., Vol. ix. p. 78.
[2] Geology of the Weald, Mem. Geol. Surv., p. 142 (1875).

The section was visited by the Geologists' Association in 1893 and described by Messrs. Monckton and Mangles, but they seem to have seen only the upper part. They found the following fossils in the second (or middle) bed of phosphate nodules:—*Nautilus* (a fragment), *Ammonites Beudanti*, *Am. interruptus*, *Natica sp.*, *Pecten orbicularis*, and *Neithea quinquecostata*.[1]

The writers discuss the correlation of these beds, and are in doubt whether to refer them to the zone of *Am. interruptus* or to that of *Am. mammillatus;* but Mr. Monckton informs me that he has since found a specimen of *Am. mammillatus* in the same fossiliferous bed, and this may be considered to decide the question. I agree with him, therefore, in regarding beds I have bracketed as representing the zone of *Am. mammillatus*, with a thickness of about 15 feet.

Upper Gault and Upper Greensand.

No good section of these beds is seen in the east of Surrey till we come to Godstone. In the early part of this century, up to about 1830, the *firestone* of Godstone and Merstham was largely quarried both for building-stone and for stone to line fire-places and furnaces. The quarries have been mentioned and described by many writers, notably by Webster,[2] W. Phillips,[3] and Fitton.[4]

It would appear that in Fitton's time only a small thickness of the Malmstone was worked, and that this was in the Firestone part of the series, whereas the bed now chiefly worked is the "hearthstone" which lies above the "firestone." Fitton says the stone was obtained by an adit between five and six feet in height, and the following is the succession which he gives:—

	Ft.	in.
1. *Hard roof*, a uniform fine grained sandstone effervescing strongly with acids, and easily cut into any desired form. It forms a roof of such firmness as to support itself for a width of 17 feet.	1	3
2. *Firestone* ("Green bed" of the workmen). Stone like that of the roof but harder and somewhat finer in grain, in three layers, about - -	4	0
3. A bed of bluish-grey siliceous concretions called "flints" by the workmen, embedded in hard grey siliceous stone, from 3 inches to - -	0	4
4. *Firestone* like No. 2 - - -	0	10
5. Quarry floor, stone unfit for working from its containing much flinty [cherty] matter.		
	6	5

Of Merstham Fitton gives the following account:—"Merstham occupies nearly the middle line which has been worked upon for firestone; the extreme points to which the quarries have extended of late years [*i.e.* before 1827] being near Godstone on the east and Buckland Green on the west. . . . The beds

[1] Proc. Geol. Assoc., Vol. xiii. p. 17.
[2] Trans. Geol. Soc., Ser. 1, Vol. v. p. 355.
[3] Outlines of the Geology of England and Wales (1822), p. 150.
[4] Trans. Geol. Soc., Ser. 2, Vol. iv. p. 137.

dip at a very small angle towards the north, and those which include the firestone are visible to a thickness of about thirty feet, projecting like a step beyond the foot of the Chalk escarpment. The works had been discontinued for some time before I visited the place, but the following list of the strata was given to me by the person who had superintended them:—

	Ft.
a. "*Roof*"—sand 2 feet, soft stone 2 feet. This stratum is of great firmness and stability, the roof supporting itself perfectly in the drifts, which are 30 feet wide - -	4
b. "*Firestone*," including "flints" (cherts) about two feet from the top - -	5½
c. "*Good hard building-stone*" -	2
d. "Burry stone," about	16
Gault "marl" below.	
Total	25 to 27

He states in a note that "a well at the Feathers Inn is 150 feet in depth with a boring of 60 feet at the bottom, in the whole 210 feet, all in clay and marl. . . . The water rose to within 40 or 50 feet of the surface. Much sand which had come up through the bore was afterwards found at the bottom of the well."

Of the Godstone quarries Dr. Hinde[1] writes in 1885:—"There is here an upper bed of soft rock 5 to 8 feet in thickness, which is largely quarried for hearthstone. This rock is of a more friable character and contains more calcite than the Malm or Firestone. Beneath the hearthstone bed there are two beds 14 feet in thickness of Malm or Firestone similar to those at Merstham, and filled with sponge remains. In them there are at intervals parallel layers of the hard blue aggregations known as flints."

In 1896 the quarries about 1 mile north of Godstone were still worked. One about ¼ mile east of the London Road penetrates about 130 yards under the hill. The rock quarried in angular lumps is used chiefly for cleaning hearths, little being used for building. In the quarries immediately west of the London road a large number of slabs of a size suitable for hearthstones were drying in open sheds.

About 250 yards still further west an open-air quarry gave the following section in quite the upper part of the Greensand:—

	Ft.	*in.*
Soil, &c. - -	3	0
Soft green-grey micaceous glauconitic sand *Avicula gryphœoides* - -	3	6
Lighter grey micaceous sand - -	6	0
A layer of separated dogger-like masses in soft grey micaceous sand - - -	2	9
Firm grey glauconitic sandy rock seen for 5 to -	6	0
	20	3

To the east an old part of the quarry showed the uppermost bed of green-grey sand to be 6 or 7 feet thick.

Topley[2] says the total thickness of the Upper Greensand near

[1] On the beds of sponge remains in the Upper Greensand and Lower Greensand of England. Phil. Trans. Roy. Soc., Part II. 1885, p. 415.
[2] Geology of the Weald, p. 154.

Godstone is perhaps about 25 or 30 feet, but the above notes indicate a thickness of at least 38 feet.[1]

Writing in 1885, Dr. Hinde gives the following section as visible in a quarry 1½ miles east of Merstham:—

	Ft.	in.
1. Siliceous and siliceo-calcareous rock in thin beds -	5	0
2. Similar rock, but in large compressed nodules which in places decompose to a reddish clay - - -	0	8
3. Beds of siliceo-calcareous rock, Firestone or Malm -	10	0
	15	0

He describes these beds of rock as "when fresh of a light brown tint and earthy aspect; they become white or grayish-white when dry, and are then considerably harder. The rock is minutely porous and largely absorbent of water, and when dry of light specific gravity. . . In some places the light brown rock passes into one which is heavier, more compact, and of a light bluish tint, and frequently becomes nodular. These nodules are locally known as flints," but, as he remarks further on, "they are not sharply delimitated from the enclosing rock, in the same manner as the flints in the chalk, but there is a gradual passage from one to the other." Dr. Hinde found the rock, on microscopical examination, to be full of sponge-spicules, but "did not meet with a single entire sponge or even a fragment of one." So far as we can ascertain no one has recorded a fossil of any kind from the Merstham or Godstone quarries.

An excellent section showing the junction of the Chalk Marl and Upper Greensand is seen at the Colley Hill quarry about a mile N.N.W. of Reigate. The following succession was noted here by Mr. W. Hill in 1896:—

		Ft.	in.
Chalk marl, zone of *Am. varians.*	1. Soil and rubbly chalk - -	3 to 4	0
	2. Grey marly chalk drying whitish	6	0
	3. Grey marly chalk mottled with bluish grey, containing hard concretionary masses, *Ammonites varians* - - -	9	0
	4. Grey clayey marl much mottled and patched with yellowish buff, passing insensibly into the bed below -	2	0
Chloritic Marl.	5. Greyish green glauconitic sandy marl, *Ostrea vesicularis, Avicula gryphœoides*	3	0
Upper Greensand.	6. Greyish green glauconitic micaceous marly sand passing into next -	2	0
	7. Firm greyish green micaceous marly sand -	6	6
	8. Hard greyish green rock, "the Roofstone"	1	0
	9. Firm greenish grey sandstone, "Hearthstone" - - - - - - -	6	3
	10. Hard green-grey rock	1	0
	11. Firm green-grey sandstone, "Hearthstone	4	0
		43	9

Beds 4, 5, 6, 7 pass down into each other so insensibly that no line can be drawn, though by standing a little way off some difference in each is shown by the weathering.

Visiting this quarry again in 1897 the workings were found to

[1] More recent information indicates a thickness of 55 feet. *See* Proc. Geol. Assoc., Vol. xvi., p. 162 (1899).

be much extended, and about 10 feet of the lower hearth stone exposed. It was also seen that huge lenticular masses some yards in length and two or three in thickness had slipped from their original position down the slope of the hill, yet retaining their horizontal position.

Mr. C. E. Hawkins has communicated a detailed account of the succession visible at the Brockham quarry in 1879, when he was able to measure a long exposure of the beds from the base of the Chalk to the clays of the Gault. The following is some what condensed from Mr. Hawkins' notes.

"The base of the Chalk Marl is rather sandy, and passes abruptly into a green sandy and marly bed, but there is no line of division between the two. This passes rapidly down into olive-green micaceous sand, of which there is about 12 feet. This sand rests on a seam of hard sandstone a few inches thick, below which is greenish grey sand about four feet thick, more micaceous, and becoming hard at the base. In another pit the seam of hard sandstone forms the "roof-stone" to a tunnel which is excavated entirely in the Hearthstone, no attempt being made to work the underlying Firestone.

"Thirty yards south of this, and at a slightly higher level, the Firestone is seen cropping out at the surface. It is much jointed in every direction, and even rubbly in places. The stone varies much in hardness, some of it being very hard and some soft and friable. The colour is drab when first quarried, but it soon turns white on exposure to the air. It contains siliceous, micaceous, and calcareous constituents, but glauconite is not conspicuous. The firestone proper may be 18 feet in thickness, and it dies out below in a bed of sandstone which weathers grey and contains a layer of brownish calcareous nodules at the base. The dip of the Firestone is 21½° in a direction about 7° east of north."

Below this, and in continuous succession, Mr. Hawkins saw a long series of sandy marls, the particulars of which are given below, but we briefly repeat the beds above described so that the reader may have the complete vertical section before him:—

Section seen at Brockham Quarry in 1879.

		Feet.
Greensands.	Green marly sand.	
	Olive-green sand - - - -	12
	Hard sandstone - - - - - -	? 0½
	Greenish-grey sand and sandstone - -	4
Malmstone, 34 feet.	Hearthstone worked by tunnelling, about	8
	Firestone seen at the outcrop	18
	Friable green sandstone - -	2
	Drab-coloured sandy marl, containing scattered masses of hard stone like the firestone, about	6
Sandy marls and marly stone, 82 feet.	Grey marl with very little stone - - -	3
	Hard rubbly and marly stone - - -	6
	Hard marl and marly stone, from 10 to - - -	12
	Softer clayey marl - - -	6
	Sandy marl indurated in places - -	6
	Indurated marl, becoming harder and more massive in the lower part - -	12
	Sandy marl, much indurated in the middle part from 12 to 30 feet down and with a layer of hard stone at the base - - - -	36
Gault.	Marly clay passing into sandy clay - - - - -	5

Mr. Hawkins considers that the sandy marls down to the lowest layer of stone should be classed as Upper Greensand, and he has adopted this view in drawing the line for the base of the Upper Greensand in Hampshire. We neither endorse nor differ from this view, for a glance at the diagram, Fig. 51, will show that the base of the Upper Greensand continually changes its stratigraphical horizon and descends to lower and lower levels as the observer passes from east to west.

The following notes are contributed by Mr. Hill from observations made in 1896:—

The exposures seen by Mr. Hawkins at Brockham are not now visible; but the base of the Upper Greensand is seen in the cutting of a tram-road, while the top of the Gault is seen in a clay-pit just below, the actual junction being unfortunately hidden. The lowest bed of the Upper Greensand was a soft silty marl of a grey-brown or drab colour, while the uppermost bed of the Gault, seen a few yards further on, is a rather sandy clay almost of the same tint. Clay of similar character was exposed at the top of the clay-pit, where the continuing section was as follows:—

	Ft.	in.
Grey rather sandy or silty clay much stained with rusty colour in the jointings at its base	15	0
Blue-grey clay, the colour rapidly deepening to a dark bluish grey	12	0

There were no fossils of any kind in this Gault.

A cutting for railway-purposes at Betchworth Station showed the following section of the Upper Greensand below the Firestone:—

	Ft.	in.
Soil and rubble	2	0
Firm rather silty than sandy marl	6	0
An irregular layer of hard concretionary (?siliceous) masses, iron-stained exteriorly	0	9
Greyish, rather soft silty marl with irregular layers of hard concretionary stone, *Ammonites auritus*	7	9
Firm grey glauconitic silty marl without hard masses	10	0
	26	6

The silty marl weathers into knobs about the size of a large walnut with a curious conchoidal fracture. Further east another hard bed is seen coming in. Topley[1] gives a section of the upper part of the Greensand near Betchworth Station a little south-east of Hill (? Holmes) Farm, which runs thus:—

	Ft.	in.
Gravel made up of flints and chalk	3	0
Soft calcareous sand with much green matter	12	0
Hearthstone	11	0
Firestone	12	0

[1] Geology of the Weald, p. 154.

A section in a small quarry ¼ mile west of Puttenham deserve recording; it is probably above the main mass of the Malmstone:—

	Ft.	in.
Firm marly light grey rock, *Avicula gryphæoides*, *Pseudodiadema Benettiæ*, and *Cardiaster fossarius* (?) -	4	0
Very hard yellowish-grey glauconitic rock - - -	1	6
A seam of dark grey clayey marl - - - - -	0	2
Softish grey calcareous rock, *Pecten orbicularis* - -	0	6
Very hard yellowish-grey rock - - - - - - -	1	2
	7	4

Between Puttenham and Farnham a quarry ¼ mile N.N.W. of Shoelands Farm gave the following section, interesting because it seems the first in proceeding from east to west where the Greensand begins to put on the light-coloured chalky aspect of the Hampshire Malm:—

	Ft.	in.
Soil and rubble - - - - - - - - -	1	6
Pale grey micaceous and glauconitic rock in massive beds (Malmstone) - - - - -	6	0
Pale grey marl, soft, sandy, glauconitic and micaceous -	2	6
Sandy, micaceous, slightly glauconitic rock in massive blocks (Malmstone) - - - - - - -		6
Marly rock weathering in platy pieces -	1	0
Exceedingly hard grey rock, sandy, glauconitic and micaceous, in massive angular blocks - seen for	8	0
	25	6

The lowest bed was being quarried for building-purposes. The blocks are pale grey exteriorly, but when split disclose a central part of slaty grey. No fossils were seen.

CHAPTER VII.

GAULT AND UPPER GREENSAND (SELBORNIAN) IN HAMPSHIRE.

General Description.

On the borders of Surrey and Hants the dip of the strata is N.N.W., but this gradually changes to a westerly dip, so that near Alton the Gault and Greensand are dipping westward beneath a range of Chalk Hills that strike from north to south. The inclination, however, is slight, so that in the valley of the Wey and around Binsted the Selbornian clays, marls, and sandstones occupy a considerable area of ground.

As a consequence of the low angle of dip and of the greater development of siliceous rock in the higher part of the formation, the physical features presented by the malmstone area contrast strikingly with those of the area occupied by the marls and clays. The malmstone tract forms a broad terrace between the slopes of the Chalk on the west and the still lower clay lands of the Gault on the east; the soil of this terrace is dry and fertile; it is furrowed by deep valleys and runs out into broad plateaus terminating in steep escarpments, at the foot of which strong springs break out. The Gault plains below have a heavy soil except where this is covered by a gravelly deposit consisting of cherts and flints, the insoluble remnants of the Greensand and Chalk which once extended over them. In early times they formed part of the dense forest area of the Weald.

Of the Gault Sir R. I. Murchison says "its line is marked by the most fertile water-meadows and the finest forest timber; thus presenting a *green* belt which clearly defines and distinguishes it from the rich wheat land of the malm rock above and the arid expanse of the Lower Greensand below."[1]

In Hampshire, then, the natural division of the Selbornian into Gault and Malmstone is specially obvious; but though it is quite right that this should be recognised and that the two different rock-materials should receive different colours on a geological map, it is wrong to class them as separate and distinct stages, because such an arrangement is not confirmed by fossil evidence. The fossils of the malmstone are substantially those of the Upper Gault of Folkestone, and hence we regard the malm as merely a lenticular development of stone in the zone of *Ammonites rostratus* (see ante, p. 93).

As regards the lower limit of the Gault we have little information. So far as we can ascertain *Ammonites mammillatus* has only been obtained from one locality in Hampshire

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[1] Trans. Geol. Soc., Ser. 2, Vol. ii. p. 100.

(near Alton), and the character of the beds at the base of the Gault seems to vary considerably. In some places it consists of green sandy clay with phosphatic nodules, and in a section recorded by Mr. Topley this passes down into a brownish sand with pebbles; but there are also places where a rapid change occurs from yellow sand to clay without the occurrence of any greensand, phosphates, or pebbles, and in these places the zone of *Am. mammillatus* may be absent.

We have no doubt that the zone of *Am. interruptus* is continuous through the county, but so far as we can learn that species has only yet been recorded from Alice Holt forest,[1] and from the railway cutting north-west of Alton.[2] We have likewise no doubt that part of the Gault of Hants belongs to the zone of *Ammonites rostratus*, for that fossil occurs in its upper beds at Bradshott, near Selborne (*see* p. 106).

The highest part of what has been mapped as Gault is a fine micaceous sandy marl, and this passes up into the malmstone. The lower part of this is a soft grey or buff friable stone, but the higher part contains beds of massive freestone, so white and chalk-like that it might easily be mistaken for Chalk unless closely examined. In this malmstone *Ammonites rostratus* is not uncommon. In its upper part layers and lenticular lumps of hard siliceous cherty stone occur, sometimes forming regular courses of hard rock (locally called "ragstone").

Gilbert White of Selborne was the first to give a description of the Hampshire malmstone; he calls it freestone or white malm, and says (in Letter IV.), "This stone is in great request for hearthstones, and the beds of ovens, and in lining of limekilns it turns to good account. . . . When chiselled smooth it makes elegant fronts for houses. . . . It is a freestone cutting in all directions, yet it has something of a grain parallel with the horizon, and therefore should not be surbedded, but laid in the same position that it grows in the quarry." He also remarks in Letter III., "In the very thickest strata of our freestone and at considerable depths well-diggers often find large scallops, or *pectines*, having both shells deeply striated and ridged and furrowed alternately." It would be interesting to learn whether these *Pectens* were *P. asper* or *P. Beaveri*.

With respect to the upper limit of the Greensand the summit is clearly marked in the northern part of the county, where a glauconitic marl rests directly on a non-glauconitic silty marl belonging to the Malmstone group. This succession was described by Mr. Bristow in the Geological Survey Explanation of Sheet 12, and was quoted by Mr. Topley in his Memoir on the Geology of the Weald (1876, p. 156). We consider that Mr. Bristow was right in regarding the glauconitic bed as "Chloritic Marl," and not Upper Greensand; in other words it may be taken as the base of the Chalk Marl.

South of Alton, however, a bed of bright green sand comes in

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[1] By Murchison as *Ammonites dentatus* in Trans. Geol. Soc., Ser. 2, Vol. ii p. 100 (1825).

[2] By Mr. Etheridge in Mem. Geol. Surv., Sh. 12.

between the Chloritic Marl and the malmstone, and this we think is rightly referred to the Upper Greensand. The question then arises whether this bed of greensand belongs to the zone of *Ammonites rostratus* or to that of *Pecten asper*. Dr. Barrois referred it to the latter,[1] but he did not record any fossils from it, and we feel very doubtful whether it can be regarded as representing the highest part of the Greensand in Wiltshire or the Isle of Wight.

The geology of this part of Hampshire has been neglected since the early part of the century, and more careful collecting of the fossils is required before any positive opinion can be expressed with regard to these highest beds. Mr. W. Curtis of Alton was a diligent collector of local fossils from about 1840 to 1860, and his specimens are now in the Curtis Museum at Alton. His collection of Malmstone fossils includes a fine example of *Pecten asper*, though whether this was found in association with *Am. rostratus* is not recorded. Inasmuch as *Pecten asper* has been found occasionally in the zone of *Ammonites rostratus* in France we are not disposed to attach much importance to the occurrence of a single specimen in Hampshire.

We doubt therefore whether any part of the Malmstone can be regarded as the equivalent of the Chert Beds of more western localities, and with respect to the overlying micaceous greensand we can only say that it does not resemble the sharp quartzose greensand which generally overlies those beds in Wiltshire. The succession in this part of Hampshire is in fact similar to that in Surrey.

In the north-west of Hampshire, however, between Kingsclere and Burghclere, there is an inlier of Selbornian Beds which approximate to the Wiltshire type and include greenish sands with *Pecten asper*. It is evident, then, that this zone comes in between Farnham and Kingsclere.

With respect to the thickness of this stage in Hants the evidence that is available points to its being great, but does not allow us to give a definite estimate.

Both Gault and Greensand boundaries have been mapped by Mr. Hawkins, and the relative levels at different places show that the thickness of the Gault cannot be less than 100 feet, but is not likely to be much more if the sandy marls with occasional layers of stone are included in the Malmstone.

East of Selborne, at Temple Farm, and again to the north-east at Candover Farm, there are ridges of malmstone which rise to a height of 170 feet above the line drawn for the base of this division and do not reach its top.

From this evidence, therefore, it would appear that the total thickness of Gault clays, sandy marls and malmstone, is not less than 280 feet near Selborne.

There is some confirmation of this in a boring made many years ago at Ashdell in Alton which was carried through the Lower Chalk, Malmstone, and Gault to the Lower Greensand. The

[1] Recherches sur le Terr. Cret. Sup. 1876, p. 36.

Gault is given as 150 feet and the Malmstone as 80, but it is probable that another 50 or 60 feet should be assigned to the latter.

It may be mentioned that Sir R. I. Murchison observed that wells dug in the Malmstone vary from 60 to 100 feet in depth;[1] also that Mr. Topley estimated the thickness of the rock near Petersfield to be 80 feet and that of the Gault at 100 feet.[2]

Stratigraphical Details.

Gault.

"The ground occupied by the Gault is for the most part flat, but rises somewhat toward the escarpment of the Upper Greensand, where the slope thus made is covered with fallen masses of the higher formation. It is still a good deal covered with oak, for which in former times it was celebrated." [3]

Little is yet known about the Gault ot Hampshire, for there are not many brickyards, and those we have seen have but shallow excavations. The lower part is a stiff blue clay, but the higher beds are marly and silty, passing gradually into silty malm.

Mr. Hawkins saw the junction-beds at Cradle Lane, ¼ mile south-west of Holt Hatch Farm, some three miles south-west of Farnham, and he describes them as "the green sandy beds."

The following fossils are recorded in the Geological Survey Memoir on Sheet 12 (1862) as having been found in the railway cutting which traverses the Gault north-east of Alton:—

Ammonites interruptus.	Arca.
" lautus.	Pentracrinus.
" mammillatus.	Serpula.
" tuberculatus.	Lamna.
Inoceramus concentricus.	

In the brickyard at Bradshott, about two miles south-east of Selborne, and from 15 to 20 feet below the base of the malmstone, the following section was seen by Mr. W. Hill in 1897:—

	Ft.	*in.*
Clayey soil	3	0
Bluish grey clay mottled with brown	3	0
Bluish grey clay with hard stony phosphatic (?) nodules ("stone") (*Am. rostratus*)	2	6
Bluish grey clay, passing rapidly down to very tough brown clay, *Inoc. sulcatus, Nucula pectinata, Dentalium sp.*	1	6
Tough brown clay with *Inoc. sulcatus* in a marked layer, Am.	7—8	0
	17	0

[1] Trans. Geol. Soc. Ser. 2, Vol. ii. p. 99.

[2] Geology of the Weald. Diagram on Plate IV.

[3] F. Drew, quoted by Mr. Bristow in the Geol. Survey Memoir on Sh. 12, p. 4 (1862).

This section appears to be entirely in Upper Gault. The fossils here were plentiful, but all were in soft clay and difficult to preserve; there were none of the hard phosphatised casts so common in the clay pits along the base of the North Downs.

Topley[1] gives the following section of the basement beds of the Gault at the southern corner of Steep Common:—

		Ft.	in.
Gault	5. Green sandy clay - - - - - -	2	0
	4. Green sandy clay with phosphatic nodules -	1	0
	3. Brown and green sand with large pebbles and at one place phosphatic nodules at base - - - - -	2	0
Folkestone Beds	2. White sand with laminæ of clay - -	6	0
	1. White sand - - -	10	0

We incline to regard bed 3 as the base of the Gault, and it may possibly represent the zone of *Am. mammillatus.* Topley says "it is uncertain how far to the west the phosphatic nodules continue (*op. cit.* p. 150).

In 1897 the base of the Gault was seen in a field just south of the main road between the Seven Stars Inn and Stroud Farm about 1¼ miles west of Petersfield; here there was a passage in about 2½ feet from sharp yellow sand to stiff blue clay; there was no greensand, pebbles, or phosphatic nodules; this exposure cannot be more than 1½ or 2 miles west of that recorded by Mr. Topley. Some 300 yards west of the Seven Stars Inn is a brickyard with shallow workings in stiff blue clay; no fossils were found.

Upper Greensand (Malmstone).

Messrs. Paine and Way were the first to describe the special mineral characters and chemical composition of the malmstone near Farnham.[2] Even when they first wrote the lower part of the stone was dug for use as a kind of manure, and on analysing a sample of this lower part they found that it contained no less than 46 per cent. of soluble silica. They subsequently investigated the higher parts of the formation, and had two long trenches dug across the outcrop on Mr. Paine's own farm, and one of these was carried from the outcrop of the Chloritic Marl to the beds which pass into Gault. The account given of the

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[1] The Geology of the Weald, p. 142.

[2] See Journ. Roy. Agric. Soc., Vol. xii. p. 549, and Vol. xiv. p. 225.

beds traversed by this trench is as follows, but reversed so as to be in descending order :—

Section on "Deans Farm," from N.W to S.E.

No.	Character of Rock.	Soluble Silica.	Carbonate of Lime.
	Green marl.		
49	Thin flaky stone	13·26	62·22
48	Rotten stone	40·75	20·86
76	White building-stone, or firestone, 20 feet thick	56·62	—
77	Blue building-limestone	8·20	74·96
36	Rubbly rock, rather soft	47·55	—
37	Do. do.	40·56	—
78	Brittle rubbly rock below 39	58·52	—
39	Hard compact light rock 10 feet thick	72·	—
73	Hard layer of rock below 72	58·45	—
72	Very soft stratum, like marl, 4 feet thick, lying between 71 and 72	43·94	—
71	Hard and rather cherty looking	66·75	—
19	Hard like 22	58·67	—
36	Compact rather hard rock	47·55	—
37	Soft light crumbling rock	40·56	—
40	Do. do.	43·73	—
41	Soft rock like 12 in texture	41·73	—
22	Hard, but very light and porous	38·88	—
12	Softer rock, crumbling on exposure	37·01	—
42	Much like 12	27·81	—
75	Soft rock which readily crumbles into dust	16·03	—
13	Near the gault, approaching a clay	2·34	—

Messrs. Paine and Way considered that the vertical depth of the rock from No. 42 to 48 inclusive was about 100 feet thick, and they mention a marl-pit in Crondall Lane which showed a vertical depth of 60 feet.

The lower part is of a soft friable nature, crumbling into powder on exposure to the weather. The depth of this is from 30 to 40 feet; it contains from 25 to 40 per cent. of soluble silica and is destitute of calcic carbonate. Ascending from this, the rock becomes more compact, and contains a larger percentage of the silica, the amount varying from 40 to over 70 per cent., but in this there is often a very soft silty stratum, three or four feet thick. The higher part is a white siliceous rock containing from 50 to 60 per cent. of soluble silica and forming an excellent building-stone; this they call firestone, and say it usually contains one and sometimes two beds of blue limestone (see section, No. 77). The highest beds contain much less silica and much carbonate of lime.

They believe that this description "will generally apply to the district between Farnham and Petersfield, though the strata and their sub-divisions will vary considerably in thickness." (*Op. cit.* p. 234.)

The following villages stand on the Malmstone: Binsted, Worldham, Hartley, Selborne, Empshot, Hawkley, Langrish, and Buriton.

Mr. Hill visited Farnham in 1897 and saw the malmstone in several places in road-cuttings immediately west and west-north-west of the town, but quarries which existed in fields

and hop-gardens in this locality are now disused, and in some instances filled in, and the ground cultivated. A good section in the upper part of this formation occurs about $\frac{1}{3}$ mile south of Dippenhall Farm, about $1\frac{1}{4}$ miles west of Farnham. The beds exposed in 1897 were as follow:—

	Ft.	in.
Soil and rubble	3	6
Brownish grey, sandy, softish stone, flaggy, drying much lighter colour, with dogger-like siliceous concretions	2	0
Soft grey sandy rock, dries whiter	2	6
Line of doggers in soft sandy rock, with blue cherty interior	0	9
Rather soft silty grey-brown stone	1	6
Hard grey-brown calcareo-siliceous rock, not all of the same character, appeared to become more crystalline in huge dogger-like masses, bluish grey interiorly and extremely hard; this bed was distinctly thicker at the east end of the quarry	4	6
Soft greyish white rock with a few concretionary masses	1	6
Hard siliceous concretions in soft greyish white silty rock	1	3
Soft grey sandy rather glauconitic silty rock	3	0
Rather rough grey siliceous rock, light in the hand, with irregular cavities full of soft sandy material	1	3
Massive grey siliceous rock, light in the hand	6	6
Grey sandy rock seen for	1	0
	29	6

The massive bed, $4\frac{1}{2}$ ft. in the middle of the section is used for building. The lowest, $6\frac{1}{2}$ ft., is sent to London for manufacturing purposes.

At Highcom Farm, about $1\frac{1}{2}$ miles west-south-west of the last section, Mr. Hill found another quarry at about the same horizon, perhaps a little lower, showing the following strata:—

	Ft.	in.
Soil and rubble	2	0
Greyish white, blocky siliceous rock, rather hard, with dogger-like concretionary masses	5	6
A course of rough lumpy rock	1	0
Soft sandy silt	2	6
Massively bedded micaceous rather hard whitish-grey rock, with large concretionary masses, almost chert in their centres, seen for	10	0
	21	0

By the side of the main road from Farnham to Alton, about 250 yards short of the turning to Froyle, is another quarry which shows 10 or 12 feet of pale grey malm in alternate courses of harder and softer rock.

The pale grey malm rock is well exposed in two small roadside quarries at the eastern end of the village of Binsted, and the road-cutting leading due south from this place exhibits a long continuous section of the lower part of the malm. It is here a fairly homogeneous pale grey, almost white rock, containing harder lumps and masses which split with a conchoidal fracture

under the influence of the weather. Still further westward road-cuttings near Milt Court and Worldham show small and unimportant sections in malm rock.

Writing of the malmstone of Selborne, Dr. Hinde says,[1] "The malm rock is well shown in the quarries at this village, where a section of 15 feet is exposed; also in road cuttings. . . . It is of a much harder and more compact character than at Farnham, and contains a fair proportion of calcite, which renders it more suitable as a building material."

Probably, however, the calciferous malmstone at Selborne is only a portion of the mass, for Messrs. Paine and Way analysed three samples taken from land belonging to Sir A. K. Macdonald at Selborne, and only one contained carbonate of lime. Their results were as follows:—

No.	Remarks.	Silica.	Carb. of Lime.
1	A light yellow rock, similar to No. 73.	45·41	
2	White rock analogous in position to No. 39.	55·68	
3	Resembling No. 31 - -	26·80	13·30

The No. 31 referred to was "a hard rock with blue marks about 3 feet thick," from Dippen Hall Farm, Farnham, containing 28 per cent. of carbonate of lime, and the only specimen from the middle beds of Farnham in which a large quantity of calcic carbonate was found.

Mr. Bristow observed "beyond Norton Farm, at the intersection of the lanes, the malm rock makes its appearance in the hollow roadway and watercourse, with a bed of hard, cherty blue ragstone, about a foot thick, dipping 20° south of west at an angle of 6°."[2]

At Hawkley the malmstone can be seen in the roadway leading to Scotland Farm, and it is just to the north of this farm that the great landslip took place which was so fully described by Gilbert White[3] of Selborne.

There is a small pit in malm rock half a mile north of Stroud, and the rock is again seen in the lanes near Langrish. Dr. Barrois has remarked[4]: "Toward Langrish we come on to the zone of *Am. inflatus.* It is a grey stone, sandy, light and micaceous, containing parts that are bluish and siliceous [? beds of bluish rag]. The village of Langrish, which stands on this rock, is just like a village in Argonne, with its many woods and deep ravines on every side." In his tabular *resumé* he calls it "the *gaize* de Langrish," thus comparing it with the gaize de l'Argonne. He found many specimens of *Ammonites rostratus*

[1] On Beds of Sponge Remains, Phil. Trans. 1885, p. 416.
[2] Explanation of Sheet 12, p. 10.
[3] Letter 87. Reprinted in Topley's Geology of the Weald, p. 318.
[4] Recherches sur le Terrain Cretacé Supérieur, p. 36, 1876.

(var. *inflatus*) and *Pecten orbicularis* (var. *laminosus*). The thickness he puts at 25 metres (about 80 feet).

So far as we can learn, the only collection of fossils from the Malmstone of Hampshire is that in the Curtis Museum at Alton, and a list of these was given in a memoir of the Geological Survey published in 1862.[1] It was seen, however, that the names in this list required revision, and it was felt that the collection should be examined again. Through the kindness of Dr. W. Curtis this has been accomplished, all but some of the larger Ammonites having been sent to me for examination, and the following list is the result. Dr. Curtis informs me that the specimens were obtained from Froyle, Binsted, East Worldham, and Selborne.

Vertebrata.

Enchodus.
Lamna appendiculata, *Ag.*
Protosphyræna ferox, *Leidy.*

Cephalopoda.

Ammonites auritus, var. catillus, *Sow.* (see p.).
„ Mantelli, *Sow.* (var.).
„ rostratus, *Sow.*
Anisoceras armatus, *Sow.*
Belemnites minimus, *Lister.*
Nautilus elegans, *Sow.*
„ sp. (smooth).

Gasteropoda.

Pleurotomaria perspectiva ?, *Mant.*
„ sp.
Solarium moniliferum ?, *Mich.*
Natica Genti, *Sow* (=gaultina).

Lamellibranchiata.

Avicula gryphæoides, *Sow.*
Cardita sp.
Cucullæa carinata, *Sow.*
„ glabra, *Park.*
Inoceramus concentricus ?, *Park.*
Isoarca Agassizi ?, *P. & R.*
Lima globosa, *Sow.*
„ parallela ?, *d'Orb.*
Modiola reversa, *Sow.*

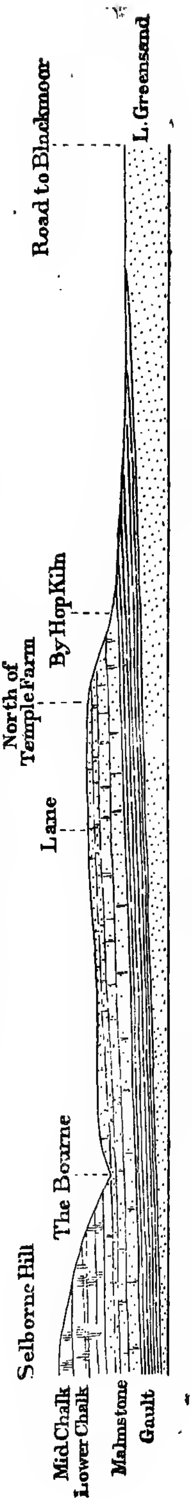

Fig. 52.—*Section through the Malmstone plateau near Selborne.*

Horizontal scale, 3 inches=1 mile. Vertical scale, 1 inch=1200 feet.
N.B.—The Gault in this section includes part of the zone of *Am. rostratus.*

[1] Geology of parts of Berkshire and Hampshire. Explanation of Sheet 12, p. 11.

Lamellibranchiata—cont.

Ostrea vesiculosa, *Sow.*
„ vesicularis, *Sow.*
Pecten asper, *Lam.*
„ elongatus, *Lam.*
„ orbicularis, *Sow.*
Pecten (Neithea) 4-costata, *Sow.*
„ „ 5-costata, *Sow.*
Pinna tegulata ?, *Eth.*
Plicatula pectinoides, *Sow.*
Spondylus gibbosus ?, *d'Orb.*

Brachiopoda.

Lingula subovalis, *Dav.*
Terebratula capillata ?, *d'Arch.*

Crustacea.

Phlyctisoma sp. ?, several chelæ of.

Annelida.

Serpula sp. ?
Serpula (Vermicularia) concava, *Sow.*

Echinodermata.

Holaster lævis, *Ag.* (casts).
Pseudodiadema (casts).
Echinospatagus murchisonianus ?, *Mant.*

The previous list includes *Ammonites varians*, but those so named are only varieties of *Am. rostratus*, and *Cardiaster fossarius*, for which the *Echinospatagus* may have been mistaken: also the following species, which do not seem to be in the Alton Museum, and could hardly be mistaken for other things:—*Baculites baculoides* (probably an error), *Natica cretacea* [= *Narica*], *Lithodomus*, *Mya mandibula*, *Unicardium ringmeriense*, *Thetis*, and *Exogyra conica*.

There are three species in the above list which have not yet been found at so low an horizon elsewhere; these are *Ammonites mantelli*, *Pecten asper*, and *Pecten elongatus*. The *Am. mantelli* (two specimens) differ somewhat from those of the Chalk Marl, having fewer and straighter ribs, more resembling the forms found in the Lower Quadersandstein of Germany, and figured by Geinitz. It is possible that they may eventually be distinguished from the true *Am. Mantelli* and its variety *navicularis*. The *Pecten asper* is unquestionable, and it would be interesting to know whether it came from a high or low horizon in the great thickness of Hampshire Malmstone. The *Pecten elongatus* is indistinguishable from the form found in the Lower Chalk; several species have been confused under this name.

Upper Greensand (Glauconitic Sand).

The highest bed of this stage in Hants is a green marly micaceous and glauconitic sand. It may be said to set in first near Alton, where a layer of brown-coated calcareo-siliceous masses are set in firm micaceous sandy marl which cannot here be distinguished from the Chloritic Marl. Near East Meon, however, there are 8 or 9 feet of firm micaceous marly sand below the layer of hard concretionary masses.

Topley[1] says, "The best section of the greensand is that

[1] The Geology of the Weald, Mem. Geol. Survey, 1876, p. 157.

exposed in the lane leading from Barrow Hill to East Meon. The banks for some distance on the south side of the lane are formed of this bed, and a good opportunity is afforded of seeing its horizontal variations. Generally it is a soft and somewhat clayey greenish sand, but hardening sometimes into an irregularly bedded green sandstone, and elsewhere into a bed somewhat resembling Malm Rock, but still with green grains. Phosphatic nodules occur, but are not very plentiful. The thickness seen is from 6 to 8 feet."

This section was seen in 1897 by one of us, but the bank had weathered down, and the opportunity for its examination was not so good as when seen by Mr. Topley. Towards East Meon the greensand seemed to pass down into a grey rather soft glauconitic sandy rock. The junction-bed with the overlying Chalk Marl was not visible.

Mr. Topley also says, "The whole thickness of the greensand may be seen by the roadside to the north-west of Barrow Hill. The chalk marl in its lowest beds contains a few green grains, which increase in numbers below, the beds at the same time becoming sandy, and thus pass into greensand. This is whitish in its upper part, but becomes darker below. Still lower it passes as gradually into Malm Rock. The thickness from good Chalk Marl to good Malm Rock is 8 to 10 feet, of good greensand about 4 feet.

The above section was looked for in 1897, but was missed; possibly it is overgrown. Dr. Barrois, however, gave an account of it in 1876, which differs somewhat from Mr. Topley's. He says, "To the north of Barrow Hill, at the point where four roads meet, the banks are cut through a coarse quartzose greensand, in beds which alternate with bands of harder grey sandstone; *Pecten laminosus* is here abundant. Following the road which leads thence toward East Meon, the bands of sandstone are seen to become less frequent, but greensand continues till it is overlain by a marly bed with dark green grains and brown phosphatic nodules."[1] He correctly refers the last to the Chloritic Marl, but the sands below he correlates with the Warminster bed (zone of *Pecten asper*).

We have not been able to visit the Kingsclere inlier, but this appears to expose a set of fossiliferous sands similar to those at the top of the formation in the Vale of Wardour and different from any seen along the main Hampshire outcrop. Mr. F. J. Bennett contributes the following note on the beds exposed in the cutting north of Burghclere Station. The cutting first shows dark compact glauconitic sand with light brown concretions, and further north are cherty beds dipping at 5° to the south. He found the following fossils:—

Nautilus elegans.	Exogyra.
Avellana cassis. ?	Cucullæa carinata ?
Pecten asper.	Vermicularia umbonata.
" elongatus.	Holaster lævis.
" orbicularis.	Discoidea subuculus.
" (Neithea) 5-costatus.	Sponge.
Lima globosa.	

[1] Recherches sur le Terr. Cret. Sup., p. 36.

CHAPTER VIII.

GAULT AND UPPER GREENSAND (SELBORNIAN) IN SUSSEX.

Western Sussex.

We shall take the western part of Sussex separately, and consider it to extend from the Hampshire border, east of Petersfield, to the valley of the Adur, a distance of about 26 miles.

Along this tract the Gault forms a strip of clay-land which is often over a mile in width, but the width of the malm-land is for the most part much narrower than in Hampshire, owing to the steeper dip. The general features of this line of country are similar to those in Hampshire, the Malmstone continuing to form a terrace with a steep escarpment overlooking the Gault plain, but this terrace is traversed at intervals by deeply cut valleys or gulleys which carry off the waters of springs rising at the base of the Chalk.

Scarcely anything is known about the Gault in Western Sussex, but it probably continues, for some distance, at any rate, to have the same characters and thickness as in Hampshire. Mr. Martin mentions that the deepest well on the Gault that he knew of (in 1828) was one in Bignor Park, and was 70 feet deep. This could not give the full thickness of the Gault, being some distance from its upper boundary.

From the space occupied by the outcrop of the malmstone and its associated sandy beds, its thickness appears to become less as it is followed eastward, but the levels near Sutton and Bignor show that it is still over 100 feet thick in that locality.

Moreover the total thickness of the Selbornian in Eastern Sussex is even greater than it is in Hampshire; hence it is probable that the clays and marls increase as the sandy beds diminish, and we may safely assume that the total thickness of Gault and Greensand in West Sussex is not less than 250 feet.

Gault.

Basement Beds.—How far the greensand with phosphatic nodules which forms the base of the Gault near Petersfield extends to the east is not yet known, but it does not reach to the outcrop south of Midhurst, for there, according to the late Mr. Topley, the junction of Gault and Lower Greensand is a red ferruginous grit without fossils or phosphate nodules.

Topley observed the same bed of red grit further east, "in the road west of Burton church, south of Petworth station; and also in many of the streams which cross the outcrop of the Gault, the hard grit often making a small fall in the stream-bed."

Still further east, at Sullington, between the valleys of the Arun and the Adur, the same red grit is seen again. Topley says "an

[1] Geology of the Weald, Mem. Geol. Survey, 1875, p. 150.

excellent section is seen in the road north-east of Sullington, where the grit is [between] two and three inches thick. Here the land below the grit is clayey for a few inches."

This junction, as seen in a cutting on the railway, near Lower Fittleworth, was described in 1869 by Mr. G. Maw,[1] who gives the section as follows:—

	Ft.	in.
Ferruginous gravel	5 or 6	0
Gault clay - - -	10	0
Hard blood-red ferruginous conglomerate - -	0	4
Yellow and orange sands which for a few inches below the conglomerate are stained bright blood-red	30	0

He describes the conglomerate as maintaining a uniform thickness of about four inches, and as abounding in small quartz pebbles, which are held together by the ferruginous matrix. He also remarks that the line of demarcation is remarkably definite, " no gradation existing between the red stratum and the Gault above or the Lower Greensand below."

Mr. R. M. Brydone, F.G.S., informs me that about 20 feet of Gault clay can now be seen in this cutting, and that fossils are very scarce and badly preserved, being all converted into selenite, which is very abundant; also that the clay is much cracked, the surfaces of the cracks being coated with rust-coloured films.

It would appear, therefore, that throughout the west of Sussex to the valley of the Adur the base of the Gault is formed by the grit-bed above described, which is not associated with any layer of phosphatic nodules. In this region, therefore, there does not seem to be any representative of the zone of *Ammonites mammillatus.*

Mr. R. M. Brydone also communicates the following information (1898):—" Some years ago a well was sunk near the base of the Gault north of Graffham, the surface of the ground at the spot being about 30 feet above the horizon of the red ferruginous grit, which is visible in the bed of a stream close at hand. The clay brought up yielded *Inoceramus concentricus* in abundance and a few other fossils." The fossils were sent to me by Mr. Brydone, but few were specifically determinable; they include the following:—

Hamites intermedius or attenuatus.
Hamites punctatus?
Aporrhais carinata.
Bellerophina minuta.
Natica clementina.?
Scalaria sp. (young).
Leda phaseolina.? and other obscure bivalves.
Inoceramus concentricus.

Mr. G. W. Lamplugh informs me that he has recently obtained fragments of *Ammonites*, which seem to be *A. interruptus* and *A. auritus*, from a brickyard at Hardham, near Pulborough.

Middle Beds.—The following notes are reproduced from Mr. Topley's Memoir on the Geology of the Weald (p. 150):—"In

[1] Geol. Mag., 1st Ser., Vol. vi. p. 335.

the railway cutting just west of Elstead Station there is a section of Gault which appears to be about in the middle of that formation. The clay here contains some hard calcareous nodules with phosphate of lime. In the road between Burton and Duncton, just opposite the road which goes off to Bound House, there are some nodular masses of clay-ironstone with the concentric structure exceedingly well marked. . . . . This section also is about the middle of the Gault."

Upper Beds.—For proof that Upper Gault with *Ammonites rostratus* exists in West Sussex below the base of the Malmstone I am indebted to Mr. Brydone, who found fossils in the marly clay forming the bed of the stream just below Duncton old church; "these included *Ammonites rostratus, Belemnites minimus, Plicatula pectinoides, Pollicipes glaber* ?," and the following among specimens sent to me for identification: *Cardita tenuicosta, Nuculana vibrayeana,* and *Fusus.*

Malm and Greensand.

The earliest description of the Selbornian in Sussex was that by Mr. P. J. Martin in 1828. He divided it into *Galt* and *Malm,* subdividing the latter into "Greensand" and "Malm-rock."[1] He says, "This [chalk] marl passes into the malm, of which there is a thin stratum [*i.e.* Chloritic marl], succeeded by a bed of greensand, and that by the more indurated malm rock, which again gradually resolves itself into the galt clay beneath."

Speaking of the bed which he specialises as "the greensand," he says "the best sections of this stratum are to be found at Steyning, Amberley, Bury, and Barlavington. . . . . at Bury it is from 15 to 20 feet in thickness."

He continues thus:—"The great body of the malm-rock next succeeds, advancing in a bold and broad talus [? terrace], at the foot of the chalk hills; and it is worthy of remark that it is broadest on the eastern side of every remarkably salient angle of the Chalk. . . . The wells are from 30 to 100 feet, and the average depth of the whole stratum may be about 70 or 80 feet." From the above description, and from a note in his memoir (p. 20), it appears that he estimated the combined thickness of the greensand and malm at from 90 to 100 feet.

Quoting Mr. Martin again:—"In its most indurated state the malm rock has a conchoidal fracture, and is of a bluish colour when fresh broken, but becoming white by exposure to air." He calls it an "argillaceous limestone," but whether it is mainly calcareous or siliceous we have not been able to ascertain.

Topley, writing of the country at and east of Buriton, says:—"Succeeding this [greensand] are the beds of malm-rock which form the Upper Greensand plateau. As seen in road-cuttings, and in some small quarries, the higher part of the malm is tolerably well bedded, and contains some hard layers of blue rag; but in descending the face of the escarpment the rag disappears, and the beds become softer and rubbly; still lower

[1] Geological Memoir on a part of Western Sussex, p. 18.

the harder portions occur only in irregular rounded masses which break up in concentric layers; and at the foot of the escarpment there are frequently some soft brown sandy beds which directly overlie the Gault.

"The exact junction with the Gault can very rarely be seen. Mr. Gould saw the lower beds well exposed in a drain at Sunwood Farm, Cocking. The marl [? malm] towards the bottom becomes a soft and rather sandy rock, with fine shining particles [? mica], ultimately passing rather suddenly into a marly clay, grey mottled with red, which changes insensibly during the next 20 feet into Gault."

Mr. C. Reid informs us that the soft glauconitic sands which form the highest part of the formation can be observed in the road-cutting by Sunwood Farm at Cocking, in the roads south of Heyshott, and in the road cutting at the foot of West Burton Hill. Similar sand is also to be seen in the railway-cutting south of Bramber Station.

Eastern Sussex.

Having described these beds in Western Sussex, it remains to give some account of their continuation through Eastern Sussex to the coast at Eastbourne.

Until recently it was supposed that the Gault maintained an average thickness of 100 feet all along the outcrop at the foot of the South Downs, while the Upper Greensand gradually decreased from about 80 feet in Hampshire to less than 30 at Eastbourne. The evidence at our command, however, shows that this is a mistake. To begin with, we have seen that if only 100 feet are referred to the Gault in Hampshire, no less than 180 feet must be assigned to the Greensand, the total being 280. Now it appears that not only is this great thickness maintained, but it is actually increased as the formation is traced eastward.

The following is an account of the boring at the Warren Farm, Rottingdean, near Brighton, taken from a plan preserved in the Mining Record Office:—

		Feet.
Chalk	Chalk with flints	460
	Chalk without flints	158
	Grey marl with occasional beds of blue marl	172
	Blue marl with occasional beds of grey marl	155
	Blue marl, sand and clay	23
Selbornian	[Upper] Greensand	7
	Gault with beds of ironstone	45
	Gault	208
	Gault with nodules	12
	Gault with beds of shells	11
	Green Gault with nodules and Ammonites	21½
	Gault with wood	10
Lower Greensand		2½
		1,285

Here there is stated to be only 7 feet of Greensand, but it is probable that the 45 feet of "gault with beds of ironstone" is

really impure malmstone, for this would make a total of 52 feet and Mr. Topley estimated the thickness of "Greensand and Malm-rock" at Hassock's Gate to be 50 feet. Beneath this the boring shows no less than 262½ feet of material which is called Gault, so that below Brighton there appears to be a total thickness of 312½ feet assignable to the combined Gault and Greensand.

If this record stood by itself one might suppose that some mistake had been made, but a boring at Beddingham Court near Lewes disclosed an even greater thickness of Gault. Mr. C. Reid obtained information and some samples from Mr. T. W. Pickwell, which show it to have traversed Upper Greensand (small thickness) and Blue Gault to the depth of 338 feet, the clay passing by two feet of clayey greensand into clean greensand, which was pierced for six feet.

Lastly, several recent borings at Eastbourne afford evidence of a combined thickness of over 300 feet. One of these was at the Eastbourne Waterworks east of the town and near the Pevensey Level, and the following particulars have been communicated by the contractors, Messrs. Legrand and Sutcliffe, the notes in brackets being by Mr. C. Reid and referring to specimens seen by him :—

——	——	Thickness.	Depth.
		Feet.	*Feet.*
Alluvium 30 ft.	Clay -	5	5
	Peat - - -	3	8
	Blue clay - -	22	30
Upper Greensand 35½ ft.	Greensand and clay [glauconitic]	29¼	59¼
	Sandstone [glauconitic] - -	¾	60
	Greenish clay and a little sand [whitish and glauconitic]	2	62
	Sandstone [glauconitic] -	3½	65½
Gault 286 ft.	Clay and stone [hard dark sandy clay] -	2	67½
	Gault with septarium (6 inches) at base - - -	171½	239
	Gault and fossils [*Inoc. sulcatus*]	102½	341½
	Gault, green veins and fossils [*Am. lautus*] -	10	351½
Lower Greensand	Gault and sand [coarse loamy sand, mixed black and green at 360 ft.] -	12	363½
	Sand [moderately coarse, with glauconitic grains at 367 ft.]	3½	367
	Gault and sand [coarse sand, with small phosphatic nodules containing glauconitic grains at 400 ft.]	65	432
Wealden -	Weald clay [light grey sandy clay at 432 ft. Dark grey clay at 436 ft. Red mottled clays down to 633 ft.].	201	633

From the above it will be seen that the combined thickness of Gault and Greensand is more than 321½ feet, for the boring begins below the top. Mr. Reid takes the Gault down to 363½ feet. (Water Supply of Sussex, pp. 56, 97.) Another boring at the Star Brewery, Old Eastbourne, makes the thickness from the base of the Chalk to the base of the Gault 308 feet.

Taken together, the three borings above-mentioned seem sufficient proof that in Eastern Sussex the thickness of the combined Gault and Greensand is over 300 feet. How much of this is referable to Lower Gault, and how much to the zone of *Ammonites rostratus*, we have not been able to ascertain, but it is known that sandy clay with *Am. rostratus* exists below the so-called Upper Greensand at Eastbourne, and we believe that this Upper Gault of Eastbourne passes westward into the malmstone. Thus, assuming that the Lower Gault maintains a thickness of 80 feet throughout the county, we think the relations of the Upper Greensand may be expressed by the accompanying diagram:—

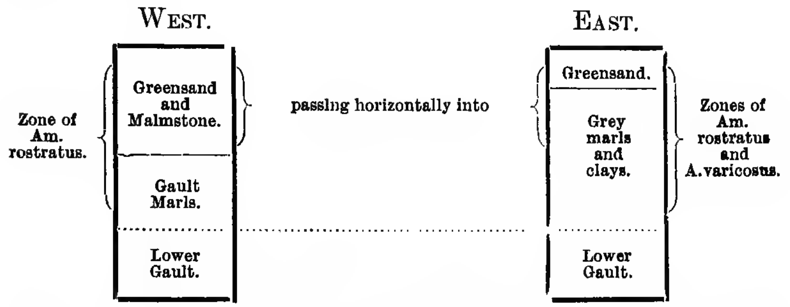

FIG. 53. *Relations of Gault and Upper Greensand at Eastbourne to the beds in western Sussex.*

Lower Gault.

In Eastern Sussex the glauconitic sand below the Gault clays and the phosphatic nodules at the junction, which are absent in Western Sussex, are again found. The following notes are quoted from Mr. Topley's Memoir:—

"A thin bed of chloritic and somewhat clayey sand which is first observed in a pit at Randles Farm near Danny (this pit exhibiting a section of the junction of the Gault clay with the Lower Greensand) continues to occur at the very top of the sand for some distance eastward; it may be seen in the old east and west road north of Lodge Farm, and again just east of Ditchling." (*Op. cit.* p. 144, from Mr. Gould's notes.)

An account of a well at Ringmer is given by Mantell,[1] who says at the bottom of the Gault there are "nodular masses of indurated marl containing an admixture of greensand with small grains of quartz. These masses are permeated by veins of splendid pyrites, and their external surface is studded with groups of cubo-octohedral crystals of the same substance."

More recently (in 1883) a boring was made on the Green at Ringmer, of which the following particulars were obtained by Mr. C. Reid:—

Gault clays -	169 feet.
Green sandy clay	20 „
Coarse sand -	28 „

[1] Fossils of the South Downs, p. 83.

Many fossils (*Ammonites, Dentalium, &c.*) were found in the upper 70 feet, *Nucula pectinata* occurred at 85 feet, and phosphatic nodules from 120 to 130 feet.

Again, at Selmeston a sand-pit by the roadside formerly showed the junction of Gault and Lower Greensand, and was seen by H. W. Bristow, whose description may be summarised as below:—

Dark olive-green clayey sand (Gault).
Grey and ferruginous sand intermixed, six inches thick, and containing small scattered phosphatic nodules and many pieces of fossil wood.
Greenish-white sand, with green grains, weathering to an ochreous-brown.

Of this section Topley remarks (*op. cit.* p. 127) that it is probably the one noted by Mantell,[1] from which he obtained the fossil named by him *Zamia sussexiensis*, but which Mr. Carruthers afterwards described as *Pinites sussexiensis*. Mr. Carruthers says "the specimen, which is, so far as I know, still unique, was found in the Lower Greensand at Selmeston, Sussex, in a bed along with water-worn fragments of stems and branches which are generally more or less perforated by boring mollusca."[2]

Mantell mentions the occurrence of a similar bed at the junction of Gault and Greensand near Willingdon, and Topley saw the junction in the railway-cutting west of Polegate Station, south of Wootton Farm. This showed the following beds:—

		Ft.	in.
Gault	Green rather clayey sand	1	6
	Layer of phosphatic nodules and fragments of wood	0	4
Lower Greensand	Red sand	1	0
	Sand getting greenish below.		

It will be noted that this is exactly the same succession as that at Selmeston.

The Gault of East Sussex has not yet been re-surveyed by the Geological Survey, and consequently we have no further information about inland exposures.

In the time of Mantell there were brickyards at Ringmer, Laughton, and Worlington, and he obtained many fossils from these, especially from the first-named locality. A list of them (with modernised names) will be found below, and from this it would appear that the Ringmer pits were in the Lower Gault.

Upper Gault.

The Upper Gault or zone of *Ammonites rostratus* has not been definitely recognised in Eastern Sussex, except at and near Eastbourne,

Mr. F. G. H. Price found an exposure of Gault clay on St. Anthony's Hill,[3] a small eminence north-east of Eastbourne and

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[1] Quart. Journ. Geol. Soc., Vol. ii. p. 51.
[2] Geol. Mag., Vol. iii. p. 541.
[3] Recorded in his Lecture on the Gault, 1879.

south of Langley Farm, and from the fossils he collected he assigned the horizon to that of his Bed 8 at Folkestone, the basement bed of the Upper Gault.

The highest beds of the Gault (our Beds 11, 12, and 13) are sometimes exposed on the foreshore near the pier, and can be seen below the site of the old Wish Tower, and again above high-water mark near Cow gap, but at the latter place, as well as under Beachy Head, they are much squeezed and disturbed. (*See* Fig. 54).

Mr. Price and Rev. H. E. Maddock obtained many fossils from the highest beds below the Wish Tower. Mr. Price says the Gault clay is hard and grey in colour; the most fossiliferous part being a sandy bed about two feet thick and situated about three feet from the base of the Upper Greensand. The fossils found in this are given in the following list, which includes all the fossils that have yet been recorded from the Gault of Eastern Sussex, though probably the list might be largely increased by the efforts of local collectors.

Fossils from the Gault of East Sussex.

——	Lower Gault.	Upper Gault.	
	Ringmer.	St. Anthony's Hill.	Eastbourne.
Corax pristodontus, *Ag.*	–	–	x
Scapanorhynchus subulatus, *Ag.*	–		x
Ammonites auritus, *Sow.*	x		x
„ denarius, *Sow.*			x
„ interruptus, *Brug.* (biplicatus of *Mantell*)	x		
„ cælonotus, *Seeley*	–	x	
„ lævigatus, *Sow.*	x	–	
„ lautus, *Sow.*	x		x
„ rostratus, *Sow.*	–		x
„ splendens, *Sow.*	x	–	x
„ tuberculatus, *Sow.*	x	–	x
„ varicosus, *Sow.*		x	x
Anisoceras armatum, *Sow.*		–	x
„ tuberculatum, *Sow.*	–		x
Belemnites minimus, *List.*	x	x	x
„ attenuatus, *Sow.*	x	x	x
Nautilus bouchardianus, *d'Orb.* (the *inæqualis* of Mantell was probably this species)	?	x	x
Hamites attenuatus, *Sow.*	x	x	x
„ intermedius, *Sow.*	x	–	–
„ maximus, *Sow.*	x		x
„ tenuis, *Sow.*	x	–	–
„ rotundus, *Sow.*	x	–	–
„ compressus, *Sow.*	x		
Aporrhais carinata, *Mant.*	x		x
Dentalium decussatum, *Sow*	x	x	x

Fossils from the Gault of East Sussex—continued.

——	Lower Gault.	Upper Gault.	
	Ringmer.	St. Anthony's Hill.	Eastbourne.
Natica Genti, *Sow.*	x	–	
Solarium ornatum, *Sow.* -	–	–	x
Avicula gryphæoides, *Sow.*	x ?	–	x
Exogyra conica, *Sow.* -	–	–	x
Inoceramus concentricus, *Park.*	x	–	x
" sulcatus, *Park.*	x	x	x
Lima globosa, *Sow.*		–	x
Ostrea vesicularis, *Lam.*	–	x	x
Nucula ovata, *Sow.*	x	x	x
" bivirgata, *Sow.*	–	x	x
" pectinata, *Sow.*	x	–	–
Pectunculus sp -	–	–	x
Pecten orbicularis, *Sow.* -	x	–	x
" raulinianus, *d'Orb.*	–	–	x
" (Neithea) 5-costatus, *Sow.* - -	–	–	x
" Barretti ?, *Seeley*	–	–	x
Plicatula pectinoides, *Sow.*	–	–	x
Rhynchonella sulcata ?, *Park.* -	–	–	x
Terebratula biplicata, *Sow.*	–	–	x
Etyus Martini, *Mant.* -	x	–	–
Hoploparia sp. - -	x	–	–
Necrocarcinus Bechei, *Desl.*	x	–	–
Palæocorystes Broderipi, *Mant.*	x	–	–
" Stokesi, *Mant.*	x	–	–
Pollicipes lævis, *Sow.* -	–	–	x
" unguis, *Sow.* -		–	x
Cidaris gaultina, *Forbes* -	–	–	x
Spatangus - - -	x	–	–
Trochocyathus harveyanus, *E. & H.* -	x	–	–
" conulus, *Phil.*	–	x	

Malmstone and Sandstone.

The views stated on p. 119 with regard to the relations between the Upper Gault and Upper Greensand of Sussex receive confirmation from the following passage in Topley's Memoir (p. 158):—

"From about Steyning, eastwards, the Upper Greensand changes its character, the beds get softer and the terrace less strongly marked. In the cutting north of Clayton Tunnel there appear to be no hard beds, the formation consisting wholly of darkish sandy marl and marly sand. Again in the cutting south of Cook's Bridge Station there are no hard layers, but the beds not far below the Chalk are soft, sandy, and rather brownish, with dark markings: they somewhat resemble malm-rock which has not become indurated. The lowest beds seen at the north end of the cutting are brownish sandy clays, becoming darker and more clayey below, the lowest beds exposed being blue and

slate-coloured clay, still rather sandy. Perhaps the greater part of this is Gault, the difference in colour being due to different degrees of dryness and weathering."

In the above description we have evidence not only of a complete passage downward from a soft kind of sandy malm into the sandy marl of the Upper Gault, but also of the lateral change from malmstone into these soft sands and marls.

It would appear from the vertical section on Plate IV. in Topley's Memoir that he estimated the thickness of the beds assignable to the Greensand and Malmstone in this district ("Hassock's Gate") to be about 50 feet.

We have no information respecting this "Greensand" portion of the formation between Clayton and Eastbourne, but it probably thins gradually toward the coast, where its thickness does not exceed 40 feet.

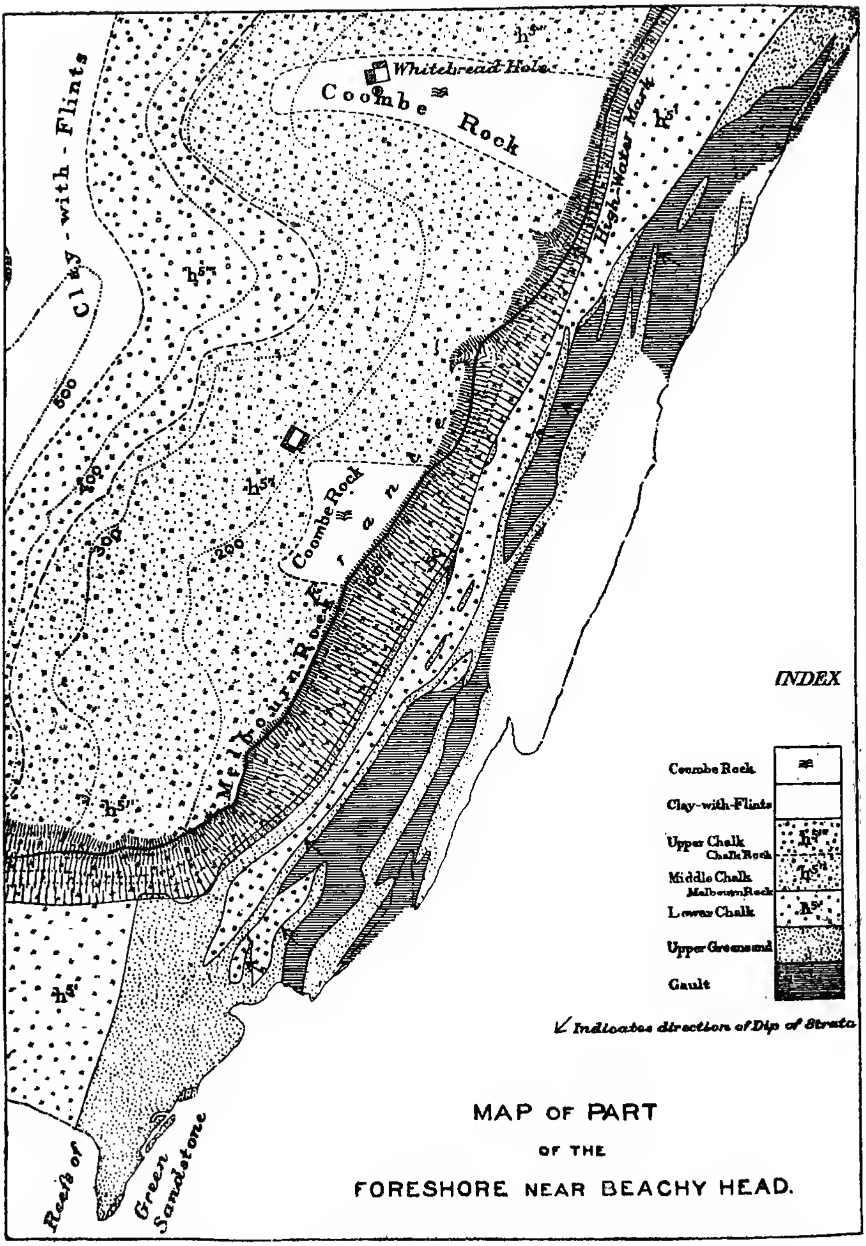
It was formerly well exposed in the cliff below and south-west of the Wish Tower at Eastbourne, but is now hidden by the erection of a sea wall. Mr. Topley gave an account of the section in his memoir "On the Geology of the Weald" (p. 159) and noted the thickness observed in the cliff to be between 22 and 24 feet, saying that "the lowest bed seen in the cliff extends towards the north-east along the shore, and passes downwards into blue Gault clay."

The Rev. H. E. Maddock, who formerly resided at Eastbourne, took careful and repeated measurements of this section, and has kindly placed the following account of it at our disposal. It was also described in 1876 by Dr. Barrois, and we give his description (somewhat abbreviated) by the side of Mr. Maddock's:—

Dr. Barrois.	*Mr. Maddock.*	*Feet.*
1. Chloritic marl.	Chloritic marl with phosphatic nodules.	
2. Rather soft green micaceous sandstone.	Greenish sand with stem-like markings of darker tint, phosphatic nodules - - - -	2
3. Light-coloured greensand with some beds of hard calcareous stone.	Soft greenish sands, light-coloured at the top, darker below -	8
	Persistent band of dark grey marly sand (2 inches).	
	Soft greenish white sand -	1
4. Greenish-grey calcareous and micaceous sandstone, with some harder beds and a few scattered phosphatic nodules.	Soft light-grey sandstone, firmer than the sand above, with a few nodules of iron pyrites	7
	Hard light-grey calcareous sandy stone - - -	1½
5. Micaceous sand or sand rock, resembling in its mineral characters the Gaize of Argonne.	Soft greenish sand - -	5
	Very dark greensand, soft and crumbling	3
		27½

Mr. Maddock thinks there may be another two or three feet of the greensand, which appeared to pass down into bluish sandy clay.

FIG. 54.—*Geological Map by C. Reid.*[1]



[1] Geology of Country around Eastbourne.

Below Beachy Head the thickness seems to be less than the above, but the beds are so slipped and squeezed that this appearance may be deceptive. Mr. Hill found a slipped mass which showed the dark grey marl band with several feet of glauconitic sand and sandstone above, and eight feet of soft grey calcareous sandstone below, the latter being destitute of glauconite and looking more like a kind of sandy chalk than a "greensand." The positions of the squeezed tracts of Gault and Greensand below Beachy Head are shown on the map, Fig. 54.

Very few fossils have been found in this Eastbourne Greensand; no Ammonites have been discovered in it. Dr. Barrois records a *Nautilus* and *Kingena lima*. Mr. Maddock has found *Pecten orbicularis*, *Plicatula pectinoides*, *Holaster lævis*, and *Jerea sp.*

Dr. Barrois in 1876 referred these sands to the zone of *Pecten asper*, but we can see no reason for such reference, and in the absence of Ammonites it is impossible to be certain how they should be classed. We incline, however, to regard the whole of them as belonging to the zone of *Ammonites rostratus*. Even the highest bed of greenish sand is somewhat micaceous, and though there are no signs of erosion at its summit, yet it is distinct as a bed from the overlying Chloritic Marl.

From the above account it will be seen that at and near Eastbourne the portion of this zone which goes by the name of Upper Greensand is comparatively thin, not more than 36 to 40 feet. The "Gault" clays, on the other hand, are very thick, and though not well exposed they have yielded a fair number of fossils.

CHAPTER IX.

GAULT AND UPPER GREENSAND (SELBORNIAN) IN THE ISLE OF WIGHT.

General Description.

The Gault and Upper Greensand of the Isle of Wight have been described in more or less detail by a long succession of writers, and some of these notices have been mentioned in our prefatory chapter (see pp. 15 and 23).

Although the broad division into blue (Gault) clays and Green (or grey glauconitic) Sand holds good here as in the south-east of England, yet there is a complete passage from Gault to Greensand through a considerable thickness of bluish micaceous silt and sand, which has sometimes been classed with the Gault and sometimes with the Greensand. Thus in the first edition of the Geological Survey Memoir on the Isle of Wight (1852) these passage-beds were included in the Upper Greensand, but in the second edition (1889) they were grouped with the Gault.

Fossils, except *Serpula* (*Vermicularia*) *concava*, are not common in these passage-beds, but as *Ammonites rostratus* has been found in the lowest part of them, at Compton Bay, rather less than 100 feet above the base of the Gault, they appear to belong to the zone of *Am. rostratus*, in which also must be included the greater part of the Greensand. It is in fact immaterial whether they are called Gault or Greensand, since the two are really inseparable and the names are merely expressions of local lithological differences between the lower and upper parts of one and the same formation (see ante p. 29).

Of late years more important questions have arisen with regard to the upper and lower limits of this formation, and different views have been expressed as to the plane of separation between Gault and Lower Greensand and also as to that which should separate Upper Greensand from "Chloritic Marl."

Until 1886 the Carstone of Lincolnshire and the upper ferruginous sands of Surrey had always been regarded as part of the Lower Greensand, but in that year Mr. Strahan suggested that they were more closely connected with the Gault than with the beds below.[1] In 1889 he also separated the highest portion of the Lower Greensand of the Isle of Wight under the name of *Carstone*, "on account of the resemblance the rock bears to the Carstone of Lincolnshire and Norfolk, of which there is reason to suppose it to be the stratigraphical equivalent";[2] and he points out that this rock passes up gradually into the Gault.

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[1] Quart. Journ. Geol. Soc., Vol. xlii. p. 486.
[2] Geology of the Isle of Wight, Mem. G. S., 2nd Edition, p. 52.

Mr. Strahan, however, does not go so far as to class this Carstone with the Gault, and he admits that the palæontological evidence, so far as it goes, indicates as close a relationship with the Lower Greensand as with the Gault. At Blackgang a doubtful *Ammonites Beudanti* and *Lima parallela* (d'Orb. non Sow.) were found in the Carstone, and these are species which only range upward into Gault; but at Redcliff *Plicatula carteroniana* and *Nuculana scapha?* occur, and these are essentially Lower Greensand species.

As I have been led to agree with those who include the zone of *Ammonites mammillatus* in the Gault, I should be prepared to admit the Carstone of the Isle of Wight into the Upper Cretaceous Series, if it could be shown to be the equivalent of that zone. This proof, however, is not yet forthcoming, for *Am. mammillatus* has neither been found at any locality in the Isle of Wight nor in the Carstone of Lincolnshire, nor in that of Norfolk; so that at present there is no sufficient evidence for regarding the Carstone of any one of these districts as representing the zone of *Am. mammillatus.*

It is true that this zone does occur in North Dorset, but the material is described as an argillaceous sand, ferruginous and oolitic, with scattered pebbles, and is hardly to be called Carstone. Moreover, since *Am. mammillatus* is now known to occur both to the eastward and westward of the Isle of Wight, it is all the more surprising that this species should not be found in that island if the zone is really represented there.

Again, if it were only a question of a few feet, as in the case of the sections at Blackgang and Niton, there would be less difficulty, but at Redcliff the thickness of the Carstone swells out to 72 feet.

I am ready to admit that the clay of the Gault in the Isle of Wight passes down into pebbly beds at the top of the Carstone, but it is by no means certain that all the beds classed as Carstone by Mr. Strahan belong to one indivisible zone or band. It is possible that the mass of the Carstone at Dunnose (Bonchurch) and Redcliff may really belong to the Lower Greensand, but that a few feet at the top may be separable as the pebbly base of the Gault, and as the equivalent of the 6 to 12 feet of Carstone at Blackgang and Compton Bay.

In this state of uncertainty it will be best not to claim the Carstone as the base of the Upper Cretaceous series, but to be content with simply drawing attention to the possibility of its including a representative of the zone of *Ammonites mammillatus.*

I quite agree with Mr. Strahan that the Lower Gault is represented in the island, and think there is little doubt that the zone of *Ammonites interruptus* can be identified. Mr. Norman records the occurrence of this species near the base of the Gault at Blackgang, but *Am. Beudanti* has been obtained by the Survey at 28 feet above the top of the Carstone near Bonchurch, and *Am. denarius* about 90 feet from the base in Compton Bay. The thickness of the Lower Gault is probably from 90 to 100 feet.

The overlying sandy clays or silts and the succeeding sandstones must be regarded as the equivalent of the Upper Gault of Folkestone, and of the Upper Gault and Malmstone of Surrey, Hants, and Sussex. They form the zone of *Ammonites rostratus*, and along the Undercliff this seems to include the beds which are known as firestone and freestone.

The Chert Beds do not contain many fossils, and have not yielded *Pecten asper;* but as they occupy the same position as those of Wiltshire, in which that fossil occurs, they are doubtless on the same stratigraphical horizon. Above the Chert Beds there is a variable set of sands and sandy marls with layers of calcareous concretions or doggers, forming a kind of passage into the Chloritic Marl. The precise horizon which is taken as the summit of the Greensand will be discussed under the head of Chloritic Marl (see Vol. II.)

The succession of beds comprising the Greensand at Culver cliff, the Undercliff, and Compton Bay is so different that it is difficult to compare them, and even along the Undercliff it is not easy to correlate the beds forming the lower part of the group. The thickness of the sands and sandstones, including the passage beds, varies from 98 to 160 feet, the greatest thickness being in the centre of the island and in the central part of the Undercliff.

STRATIGRAPHICAL DETAILS.

Lower Gault.

The clays of the Gault rest upon the Carstone or pass down into it by intercalations of pebbly beds with layers of clay. Pending the settlement of the question whether there is any representative of the zone of *Ammonites mamillatus* in the Isle of Wight, the clays of the Gault may be roughly divided into two zones—that of *Am. interruptus* below, and that of *Am. denarius* above. Whether any other zone can be made out between these two there is not yet sufficient evidence to show; but, so far as we can learn, *Am. interruptus* has only been met with in the lower 20 feet, and *Am. denarius* has only been found quite at the top.

A fair number of fossils has been obtained by the Survey from the Gault of the island, proving that it is by no means so poor in fossils as it has been represented. Careful collection on favourable opportunities would probably increase the number of species. As specimens their state of preservation leaves much to be desired, but many are sufficiently well preserved to be identifiable, and for use as zonal indicators that is all the stratigraphical geologist requires.

As already stated, we exclude from the Lower Gault the more sandy clays or "Passage Beds" between Gault and Greensand, because *Ammonites rostratus* has been found in them, and we regard them as Upper Gault. The thickness of the Lower Gault is 95 feet in Compton Bay according to Mr. Strahan's measurements, and may be as much as 105 feet elsewhere.

There are only three cliff-sections in which the Gault is well exposed, namely in Compton Bay, at Redcliff, and above Blackgang, but the lower beds can be examined in the cliff near Bonchurch.

At Redcliff the Gault is about 100 feet thick, but the lower part is seldom well exposed, being generally covered by the débris of landslips. The upper half is generally accessible, and consists of dark blue micaceous and slightly sandy or silty clay. We take the summit of this to be where it passes into a more sandy material, which is firmer and offers more resistance to the wash of the waves and dries to a light blue-grey. The Survey has obtained fossils from three horizons at Redcliff (see p. 130).

The lowest part of the Gault can be examined in the cliff east of Bonchurch, where about 30 feet of it are accessible, and from this a few fossils have been obtained at a height of about 28 feet above the junction with the Carstone (see list below).

The passage down into the Carstone is described by Mr. Strahan as follows (abbreviated):—

	Feet.
Blue micaceous clay with lines of grit	3
Brown ferruginous rock with derived phosphatic concretions containing oolitic grains of oxide of iron	1
Sandy and gritty blue clay	1
Clayey brown grit with nodules as above	3
Brown grit with many small pebbles, and a layer of pebbles at the base	26

The whole of the Gault comes into view at Blackgang, but is not easily accessible. *Lima parallela, Pecten orbicularis,* and *Avicula sp.* were found in the lower 20 feet above Southlands House; *Inoceramus sulcatus* and *In. concentricus* have also been found in a gulley west of the hotel.

The best and most easily accessible section of Gault in the island is that exposed in the cliff of Compton Bay. Mr. Strahan has given a section of this,[1] which I have re-arranged to show how much of it may be regarded as Lower Gault:—

		Feet.
Dark blue clay with *Ammonites rostratus*		8
Lower Gault	Greenish clay	2
	Dark blue clay with many fossils	20
	Blue clay	73
Carstone—Brown sand with a pebble-bed 3 inches thick at the base		6

The fossils obtained from the upper part of this section are included in the following list.

Mr. Norman says:—"Here, after a fall of the cliff, a few fossils can be collected, chiefly from the lower portion, where most of the characteristic fossils occur. *Inoceramus sulcatus, Natica gaultina* [= *Genti*], and *Ammonites dentatus* are amongst the most prominent. The latter occurs as a hard, brittle, coal-black, polished substance, the inner whorls being permeated and held together by a hard phosphatic concretion."[2]

[1] Geology of the Isle of Wight, Mem. Geol. Surv., 2nd Edition, pp. 59, 63.
[2] Geological Guide to the Isle of Wight, 1887, p. 70.

List of Fossils from the Gault.

All these were obtained by Mr. J. Rhodes, the fossil-collector of the Survey, except those marked N, which are recorded by Mr. Norman.

—	Redcliff.			Bonchurch.	Blackgang.	Compton Bay.		Locality unknown.
	50 feet down.	40 feet down.	3 to 6 feet down.			Near base.	Upper 20 feet.	
VERTEBRATA.								
Fish remains	–	–	–	x	–	–	x	–
CEPHALOPODA.								
Ammonites Beudanti, *Brong.*	–	–	–	x	–	–	–	–
„ bouchardianus, *d'Orb.*	x	–	–		–	–	–	–
„ denarius, *Sow.* - -	–	–	–	–	–	–	x	
„ dentatus (=interruptus)	–	–	–	–	–		–	–
„ interruptus, *Brug.* -	–	–	–		–	N	–	–
Belemnites minimus, *List.*	–	–	–	–	–	–	–	x
Hamites sp.	–	–	–	–	–	–	x	–
GASTEROPODA.								
Aporrhais sp.	–	x	–	x		–	–	–
Dentalium sp. (? decussatum) -	–	–	–	–	–	–	x	–
Natica Genti, *Sow.* (=gaultina)	–	–	–	–	–	N	–	–
Solarium ornatum, *Sow.* -	–	–	–	–	–	–	–	x
Turritella sp. -	–	–	–	–	–	–	x	–
LAMELLIBRANCHIATA.								
Avicula rauliniana, *d'Orb.*	–	–	–	–	–	–	–	x
„ sp. -		x		–	x	–		–
Cardita Constanti, *d'Orb.*		–	–	–	–	–		x
„ sp.	–	–	x	x	–	–	–	–
Cardium sp. -	–	–	–	x	–	–	–	–
Cucullæa carinata, *Sow.*	–	x	–	–	–	–	x	–
„ glabra, *Sow.*	–	–	–	x	–	–	–	–
Exogyra haliotoidea, *Sow.*	–	x	–	–	–	–	–	–
Inoceramus concentricus, *Sow.*	?	?	–	?	x	–	–	–
„ sulcatus, *Sow.*	–	–	–	–	x	N	–	–
Lima globosa ?, *Sow.* -	–	–	–	–	–	–	x	–
„ parallela, *d'Orb.* (non *Sow.*)	–	–	–	–	x	–	x	–
Lucina tenera, *Sow.* -	–	–	–	–	–	–	x	
„ sp.	–	x	–	x	–	–	–	–
Modiola sp. -	–	x	–	–	–	–		–
Nucula bivirgata, *Sow.*	–	–	x	–	–	–	–	
„ pectinata, *Sow.* - -	–	–		–	–	–	–	x
Ostrea canaliculata, *Sow.* (=lateralis)	–	–		–	–	–	x	–
Pleuromya (Panopæa) plicata, *Sow.* -	–	–	–	–	–	–	x	
Pecten orbicularis, *Sow.* - -	x	x	x	x	x	–	x	–
„ cf. raulinianus, *d'Orb.*	–	–	–	–	–	–	x	
„ (Neithea) quinquecostatus, *Sow.*	x	x	–	–	–	–	x	–
Pinna sp. - - - -	–	x	–	–	–		x	–
Plicatula pectinoides (?), *Sow.*	–	x	–	–	–	–	–	–
Solen dupinianus, *d'Orb.*	–	x	–	–	–	–	–	
Terebratula sp. - -	–	x	–	–	–	–	–	–
Serpula (Vermicularia) concava, *Sow.*	–	–	–	–	–		x	
Coniferous Wood - -	–	–	–	x			–	–

Passage Beds and Upper Greensand.

ZONES OF *Ammonites rostratus* and *Cardiaster fossarius.*

In dealing with this part of the stage it will be convenient to describe first the sections visible in the southern cliffs and "Undercliff," where the formation attains a greater thickness than in the more northern exposures, and where its several portions present a more individualised aspect. This tract has always indeed been regarded as exhibiting a typical development of what is usually known as the "Upper Greensand."

The finest and most complete section is that in the cliffs below St. Catherine's Down at the south-east corner of the island. The highest portion is not easily accessible, but the beds immediately below the Chloritic Marl can be examined in fallen masses near Rocken End. The Chert Beds are well shown in the vertical face of Gore cliff, the layers of chert standing out as projecting courses while the soft sands between have been eroded by the action of wind and rain into long grooves or furrows. The freestones and upper sandstones can be traced along the foot of this cliff; the softer sands form the slope below, and the Gault comes into view as the section is followed towards Blackgang.

The first careful measurement of this section was made by Mr. F. W. Simms, who estimated the thickness of the Greensand at 104 feet and that of the passage beds at 43 feet[1]; total 147 feet.

Mr. Strahan re-measured the Greensand in 1887 and assigned to it a thickness of 121 feet, accepting Mr. Simms' estimate of the beds below, and thus making the combined thickness 164 feet.[2]

Measurements made by Mr. Hill for this Memoir in 1897 gave a thickness of nearly 60 feet from the base of the Chert Beds to the lowest layer of calcareous ragstones or doggers; this with 26 feet for the beds above and 43 feet for the "passage beds" below gives a total of 129 feet for the two zones of *Ammonites rostratus* and *Cardiaster fossarius.* Adding to this Mr Simms' estimate of 103 feet of Gault we get a thickness of 232 feet for the whole formation at this locality.

The section at Gore Cliff, as measured by Mr. W. Hill, is as follows:—

	Feet.
Chloritic Marl.	
Greenish grey glauconitic sands with two layers of calciferous concretions having brown phosphatised rinds. Not measured.	—
Soft grey glauconitic sandstone with conspicuous layers of black or grey chert - -	10
Similar sandstone with layers of calcareo-siliceous concretions which here and there pass into chalcedonic chert	12
Grey glauconitic sandstone with a layer of calcareous lumps or cornstones at base -	2
"Bastard freestone," a smooth fine-grained glauconitic sandstone weathering to a yellowish-grey or buff colour - - -	1
"Freestone," a massive fine-grained sandstone weathering a yellowish grey - - - - - - - - - -	5

[1] Quart. Journ. Geol. Soc., Vol. i. p. 76 (1845).
[2] Geology of the Isle of Wight, 2nd Ed., Mem. Geol. Survey, 1889, p. 69.

Gore cliff—*cont.*	*Feet.*
Grey sandstone, weathering buff, and containing small brown phosphatic nodules, and small ragstone lumps which weather out as rough projections - - - - - - - -	$3\frac{1}{2}$
Smooth grey sandstone with small brown phosphatic nodules	5
A series of large doggers or masses of calcareous sandstone in grey sand - - -	4
Firm grey sandstone, weathering as usual, with some phosphatic nodules and a layer of calcareous concretions in the lower part	$7\frac{1}{2}$
Course of large calcareous doggers, which are grey inside and often enclose pieces of brown phosphate	$1\frac{1}{2}$
Firm grey sandstone, weathering irregularly in harder and softer portions, a few phosphates - - -	13
Similar sandstone, but without phosphates - -	16
Course of hard and heavy doggers of compact bluish-grey siliceous limestone, from 9 inches to - - -	1
Firm yellowish sand mottled with bluish-grey - - - -	3
Bluish-grey marly micaceous sand, mottled with buff - -	$10\frac{1}{2}$
Similar sand with less of the buff mottling - -	6
Bluish-grey fine micaceous sand or silt with a layer of smooth rounded doggers of grey siliceous limestone at the base	9
	110

Another convenient spot for examining the sands and sandstones is the "Cripples' Path," which ascends the cliff south-east of Niton. Here and in the cliff to the eastward about 80 feet of the sandstones can be seen, but not more than 12 feet of the Chert Beds come into view.

The next accessible place is in St. Lawrence Shute, where about 62 feet can be measured, including about 14 feet of Chert Beds. Here the bed which corresponds to the main freestone-bed of Gore cliff contains lenticular stony lumps and masses which destroy its value as a building-stone.

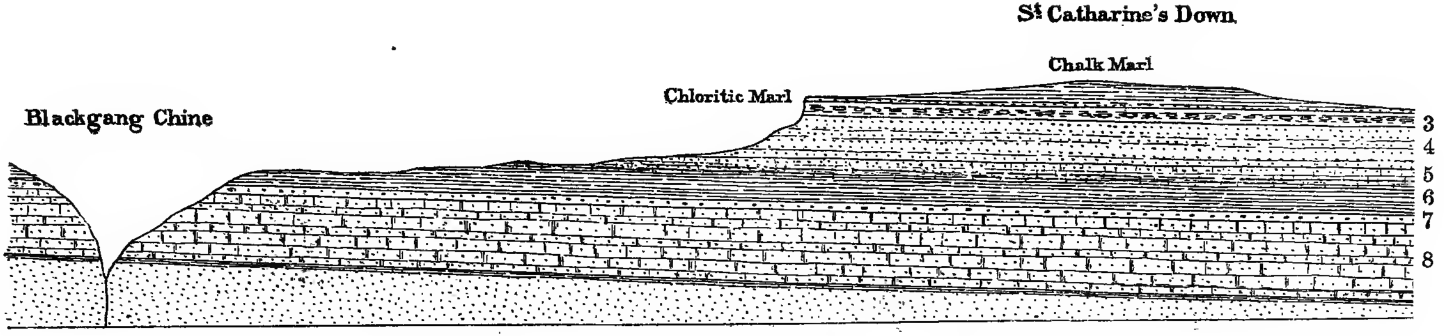
Dr. Barrois described the succession at St. Lawrence in 1876,[1] but he seems to have combined exposures on the shore or Undercliff with that in the cliff itself, and the thickness which he assigns to the lower sands is rather too great unless he included some of the bluish silty sand below the lowest layer of doggers. He gives a thickness of 134 feet to the sands and sandstones below the Chert Beds, and describes the mass of them as "soft, light, yellowish-grey sandstone, homogeneous, very micaceous, and glauconitic, with some bluish and more argillaceous layers; it resembles the *gaize* of Argonne." His list of fossils from these beds numbers 25 species, and he assigns 128 feet to the zone of *Ammonites inflatus* [*i.e. Am. rostratus*].

Mr. C. Parkinson[2] (in 1881) and Mr. M. Norman[3] (in 1882) have both described the beds overlying the Gault near Ventnor, but no such section as they give can be measured in one place. Mr. Norman informs us that his measurements were taken at various points "along the shore from Bonchurch to Niton"; Mr. Parkinson also speaks of a "section on the St. Lawrence beach," but does not otherwise specify the manner in which he measured

[1] Recherches sur le Terr. Cret. Sup., p. 106.
[2] Quart. Journ. Geol. Soc., Vol. xxxvii. p. 370
[3] Geol. Mag., Dec. 2, Vol. ix. p. 440.

FIG. 55.—*Section of St Catherine's Hill, Isle of Wight.* (A. STRAHAN.)[1]

Distance rather more than half a mile.



3. Chert Beds.
4. Sands and Sandstones.
5. Passage Beds.
6. Gault clays.
7. Carstone.
8. Sand-rock Beds.

[1] Geology of Isle of Wight, Mem. Geol. Survey, Ed. 2, Plate II.

the complete succession. Mr. Norman has resided so long at Ventnor and has collected so carefully from the various beds that we reproduce his account of them:—

	Ft.	in.
Pea-green laminated sand	2	0
Alternating Chert and sandstone beds	24	0
Firestone (hard sandstone)	2	0
Rag	1	0
Freestone (compact grey sandstone), with *Am. rostratus*, large *Nautili*, *Pectens*, and *Clatharia Lyelli*	5	0
Rag	1	0
Sandstone with a bed of rag in the middle, *Hoploparia Saxbyi* and *Am. rostratus*	7	8
Laminated sandstone with dark streaks ("black band")	1	0
Soft yellow sandstone with large flattened concretions called by quarrymen "whills"	7	0
Bed of rag	1	0
Reddish brown sandstone, few fossils, *Am. rostratus*	10	0
Rag	1	0
Reddish brown sandstone, with many fossils	10	0
Mammillated rag	0	8
Soft yellow micaceous sands with concretions and numerous fossils	30	0
Dark-coloured rag with large *Inocerami*	1	0
First bed of Gault	2	0
Hard blue rag	0	8
	107	0

The reader must remember, however, that what Mr. Norman calls beds of *rag* are not continuous layers, but courses of separate doggers or masses of hard and often compact calcareous sandstone.

The junction of the sands and the Chloritic Marl can, however, be more conveniently studied in the quarry under St. Boniface Down, about a quarter of a mile west of the Pulpit Rock. The section seen here in 1897 was as follows:—

		Ft.	in.
	Chalk marl	21	0
	Chloritic marl	7	0
Concretion Beds 5 or 6 feet	Firm grey marly sandstone piped with darker green glauconitic marl from above, and having at its base a layer of siliceo-phosphatic concretions with thick brown rinds	2	0
	An irregular bed of grey cherty concretions from 3 to	0	6
	Thin layer of grey glauconitic sand	0	4
	Prominent layer of large hard calcareo-siliceous masses with thick brown phosphatised rinds but grey centres	1	0
	Fine grey glauconitic sand with many smaller concretions of the same kind in lower part	2	0
Chert Beds	Two courses of large massive cherts with 8 inches of dark grey glauconitic marly sand between them	2	0
	Firm grey sandstone with layers of large lenticular cherts at irregular intervals	20	0

Still more recently Mr. J. B. Hue, of Ventnor, has, at my suggestion, carefully examined the sections above mentioned, with the view of ascertaining whether they could be correlated

with one another, so far at any rate as to determine whether a common horizon could be taken at the base of the sandstone group. As a result of his observations he is disposed to think that the sandstones are thickest at Ventnor and St. Lawrence, and that they become thinner to the eastward, so that beds which occupy a thickness of about 80 feet near Ventnor are only about 58 feet thick at Gore Cliff. As a consequence he believes that the lowest part of the Gore Cliff section (28½ feet) corresponds with the upper part of the beds which are called "rubble gault" by Mr. Norman, and belong to the group of sandy marls or "passage beds."

Mr. Hill and I are quite inclined to agree with this view, and have drawn up a tabular view of the suggested correlation, which is printed on the following page.[1] This view has an importance beyond the mere simplification and orderly arrangement of three independent sections, because we may infer from it that the Selbornian stage, as a whole, attains its greatest thickness at and near Ventnor, and not at Gore Cliff as was previously supposed; for if the 28½ feet of sandy marls seen at the latter place belong to the "passage beds," and were included by Mr. Simms in his estimate of 43 feet for those beds, then the total thickness of Gault and Greensand at Gore Cliff will be only 232 feet instead of about 260 as had been imagined by later writers. On the other hand the complete thickness near Ventnor is probably from 250 to 260 feet.

The chert beds and the underlying freestones have long been quarried by the railway station at Ventnor, and a good account of the section presented in this quarry has been given by Dr. G. J. Hinde, F.R.S.,[2] as follows:—

	Ft.	*in.*
Chloritic Marl (particulars not given).		
Siliceo-calcareous rock with bands of chert	21	0
Siliceo-calcareous rock	4	0
Building-stone with a nodular layer of bluish limestone	1	7
Freestone in two beds	8	0
Beds of siliceo-calcareous nodules with chert	1	4
Freestone	4	9
Hard siliceo-calcareous rock with chert	1	0
Freestone	3	0
Freestone and chert to base of quarry	3	0
	47	8

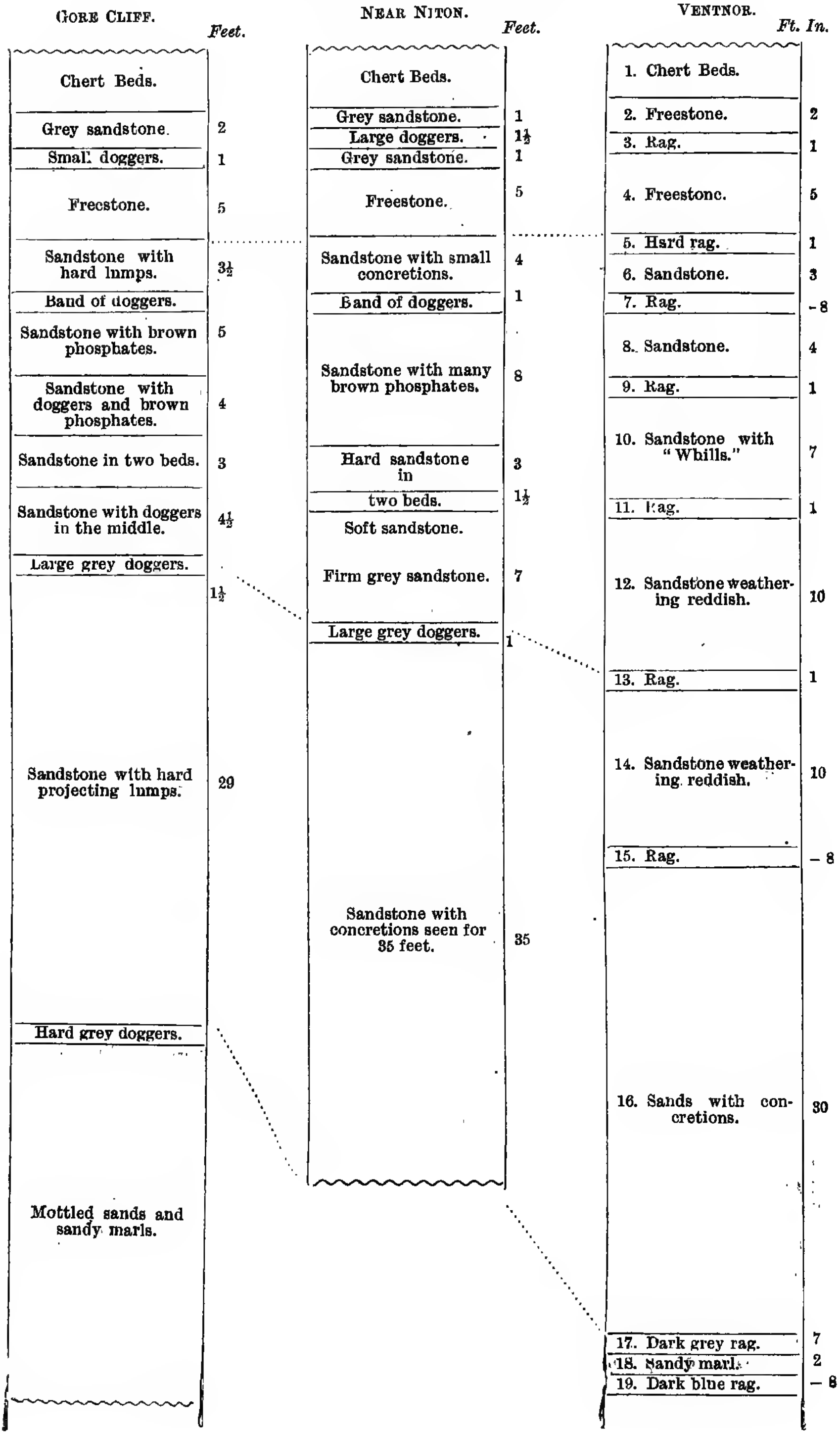
Dr. Hinde describes the higher part of the 8-foot bed of freestone as consisting of quartz-sand, glauconite, and mica cemented by calcite; the lower part and the beds below differ in having some silica in the cementing material. "The upper layers (21 feet) of this section so abound with [sponge] spicules that they may be considered as a continuous sponge bed. . . . The chert-bands are enveloped in an outer crust, of varying thickness, of white or yellow siliceous porous rock, which is interpenetrated with the empty moulds of spicules." He

[1] NOTE.—November, 1899. Mr. Hill has revisited Gore Cliff and believes this correlation to be correct.

[2] On Beds of Sponge Remains, Phil. Trans. Roy. Soc., 1885, Vol. 176, p. 417.

Fig. 56.—Comparative Sections of the Selbornian Sandstones in the Undercliff, Isle of Wight.

Scale 12 feet to an inch.



distinguishes two kinds of chert here; one is light brown in colour, and consists of chalcedonic silica full of spicules and spicular casts; the other is of a greyish or greenish-white tint, and the matrix consists of amorphous silica, only the enclosed spicules being of chalcedony.

Near Luccombe and Shanklin also there are quarries where some of the sandstones below the Chert Beds are quarried for building-stone, and particulars of them are given in the Survey Memoir on the Isle of Wight (pp. 69, 70). The quarrymen call the beds firestone, rubstone, or freestone according to the uses to which they are put; there are six beds separated from one another by layers of hard ragstone, the total depth worked for stone being between 18 and 19 feet.

We do not think, however, that this thickness of workable stone near Ventnor is to be regarded as the expansion of beds which are only 7 or 8 feet thick in Gore cliff, but consider it as due only to a greater thickness of the sandstones being free from the hard knotty concretions and lumps which occur in them further west; in other words, though the workable stone-beds increase from 8 to 18 feet, the total thickness of sandstone probably remains nearly the same.

Neither does there seem to be any palæontological reason for separating these freestones from the beds below them. Mr. Norman has given a list of fossils from them,[1] in which *Ammonites rostratus* and *A. splendens* appear, and if correctly determined these species would link the beds to the *Am. rostratus* zone. It is true that Dr. Barrois records *Pecten asper* from a bed below the Chert Beds at St. Lawrence, which he describes as "a greensand with phosphatic nodules covered with Oysters and Plicatulas," but we cannot identify this bed, nor has our fossil-collector, Mr. Rhodes, succeeded in obtaining *Pecten asper* from the Chert Beds or from any lower horizon in the island.

Combining the information derivable from the sections and observations above given, we conclude that the general succession of beds is much the same all along the Undercliff, and that it may be summarised as follows:—

	Feet.
F. Sands with layers of calciferous concretions, often partially phosphatised	about 6
E. Chert beds	22 to 24
D. Firestones and freestones	30 to 40
C. Sandstones with phosphatic nodules and courses of large calcareous doggers	
B. Rough sandstones with irregular concretions	30 to 40
A. Bluish sandy clay or micaceous silt	43 to 50
Total about	129 to 160

Beds A, B, C, D are those which we regard as forming the zone, or rather *assise*, of *Am. rostratus*; while E and F make up the higher zone of *Cardiaster fossarius*.

[1] Geol. Mag., Dec. 2, Vol. x. pl. ix. p. 440.

Passing now to the more northern exposures along the axial ridge of the island, it is stated by Mr. Strahan (*op. cit.* p. 68) that the development of the Greensand in the central parts of the island round Gatcombe, Whitcombe, Ramsdown and Shorwell is similar to that in Gore cliff. The beds change, however, rapidly both to the eastward and westward, so that the coast sections in Culver and Compton Bays differ considerably from the Undercliff and central type.

The following is an account of the section in the cliffs west of Culver Point, from notes taken by Mr. Hill in 1897:—

		Ft.	in.
	Chloritic Marl.		
F	Compact grey glauconitic sand, penetrated by patches and pipes of the overlying marl, and enclosing at the top concretions of hard siliceo-calcareous stone, *Ostrea vesiculosa* - -	1	0
	Firm grey glauconitic marly sand, streaked and mottled with darker sand, and having frequent layers of siliceo-calcareous concretions, *Ostrea vesiculosa* -	9	0
E	Firm grey marly sand, with darker streaks, containing larger siliceous concretions, some of which are converted into clear grey or black chert	2	0
	Firm grey marly sand, streaked as above, with a few brown phosphatic nodules, which are frequently arranged in short layers	6	6
	Course of large grey calcareo-siliceous doggers, some of which consist of clear grey or black chert -	1	0
C and B	Fine-grained grey glauconitic marly sandstone (enclosing brown phosphates), in beds from 3 to 4 feet thick, separated by three courses of doggers which consist of compact grey calcareo-siliceous stone - - -	16	6
	Course of hard calcareo-siliceous doggers -	1	0
	Grey marly sandstone in alternating beds of darker and lighter grey, with doggers of grey stone at irregular intervals but more or less in lines; phosphates becoming fewer - -	12	0
	Grey marly sandstone or compact sand-rock passing down into fine bluish-grey micaceous sand with scattered concretionary masses and no definite base-line. From 30 to -	35	0
A	Bluish-grey micaceous silt or sandy clay, with selenite and pyrites, weathering to a light blue-grey mudstone, *Pecten orbicularis* and *Serpula (Vermicularia) concava* - -	15	0
		98	0

From the above it will be seen that the Greensand is here very thin. The lettering indicates the probable correlation with the Undercliff section as summarised above. The Passage-beds seem here to be reduced from 43 to only 15 feet. The sands and sandstones are only 64 feet. The freestones cannot be distinguished. The Chert beds are reduced to less than 10 feet and contain very little real chert. But the beds F are thicker than anywhere else in the island; possibly they in part replace the Chert beds.

Inland there are no noticeable sections between this and the valley of the Medina, and it is only to the west of this valley that the Greensand thickens, and that layers of chert become numerous near the top. The freestone-beds are recognisable near Gatcombe, Whitcombe, and Chillerton, and Mr. Strahan found (in 1888) that they were still quarried near the last place. At Shorwell the Chert beds are quarried for building-stone, and the chert in them is white and accompanied with much chalcedony. These beds can be followed westward along the crest of the escarpment to Coombe Tower, where the feature begins to die away and the layers of chert become less numerous. (See the Survey Memoir on the island.)

There is a good section of the Greensand and of its junction with the Chalk in Brook Shute, three quarters of a mile north of Brook Church. The following account is taken from Mr. Hill's notes (1897), supplemented by some observations by Mr. Rhodes, who was sent to collect from the junction-beds:—

		Ft.	in.
Chloritic Marl	Chloritic Marl with *Ammonites varians* and *Pecten asper* - -	11	0
	Green sand with large brown calcareo-siliceous doggers, many of which are bored by *Pholas* or *Lithodomus*; these are sometimes in one, some-in two layers - From 1 to	1	6
Upper Greensand -	Grey sand with eroded surface piped by the sand above, and containing a layer of grey calcareous concretions. About - - - - -	1	0
	Soft grey glauconitic sandstone, full of hard siliceous concretions arranged in layers (but no clear chalcedonic cherts) - - - -	14	0
	A bed of darker grey very glauconitic marly sand, rather soft - -	3	6
	Firm greyish-buff sandstone with courses of large oval doggers at intervals of about 6 feet, but fewer toward the base, seen for about	60	0

There is only one layer of calciferous concretions, and the Chert Beds are reduced to 14 feet. The thickness of the under-lying sandstones is stated by Mr. Strahan to be 85 feet, and if this is so the full thickness of the Greensand would appear to be about 104 feet, without the "passage beds," which we include in the zone of *Ammonites rostratus*, and which are referred to the Gault by Mr. Strahan.

The section near Brook enables us the better to comprehend that in Compton Bay, which differs much from that of Gore Cliff, though not so much as the section at Culver. The following account of the Compton Bay section through the Gault and

Greensand is chiefly from detailed notes taken by Mr. Rhodes in 1897, supplemented by a few notes by Mr. Hill:—

		Ft.	in.
	Chloritic Marl with nodule-bed at base, resting on an eroded surface of bed below.		
F	Greenish-grey sand with pipes and borings filled with darker green sand from above, from 1 to	1	6
	Firm grey glauconitic sand with layers of small doggers of grey calcareous stone	3	0
E	Firm glauconitic sandstone with frequent layers of siliceo-calcareous doggers	7	0
D	Grey glauconitic sand with a course of large grey doggers near the middle and another at base	12	0
C	Softer dark-grey glauconitic sand, with many scattered nearly black phosphatic nodules and some hard nodular masses in lower part	8	0
	Course of rough brown doggers of glauconitic ragstone	1	0
	Soft brown yellowish sand	7	0
	Course of large grey doggers	1	6
	Yellowish-grey glauconitic sand with occasional dogger-like lumps not in lines	15	0
	Course of doggers of dark-grey stone, weathering brown	1	0
	Yellowish-grey sand	7	0
	Course of brown doggers of dark-grey stone	1	0
B	Grey sand weathering yellowish brown, with dark mottlings and two irregular courses of calcareous doggers in the lower part	12	0
	Hard dark-grey sandstone	0	6
	Streaky sand, brown and black, with an irregular layer of doggers at base	7	0
A	*Passage Beds*—dark sandy micaceous clay.		
		88	6

Mr. Strahan gives the following details of the passage-beds:—

	Feet.
Hard blue clayey bands with fucoidal markings alternating with sandy bands	6
Pale-blue silty sand or sandy micaceous clay with fucoidal markings, weathering yellow	30
Sandy clay as above, but of a deeper blue	8

Mr. Rhodes found the following fossils in the 8-foot bed of sand (23 feet from top): *Ammonites rostratus, Pecten orbicularis, Lima sp., Pleuromya.* In the lowest part of the Passage beds he found *Am. rostratus, Ostrea canaliculata, Cardita sp.,* and Fish-remains.

The total thickness of the two zones here, therefore, appears to be about 132 feet. The Passage-beds are quite as thick as at St. Catherine's. The sands above, too, show no diminution. The overlying beds with layers of doggers are about 41 feet, while the succeeding 12 feet of grey sand may represent the freestones of more western and southern localities. The Chert beds are reduced to 7 or 8 feet of sandstone with calcareous concretions instead of cherts, and the "concretion beds" F are 4½ feet thick with an eroded surface.

In the following list of fossils from the Upper Greensand we have attempted to show the vertical distribution of the species, but it will be seen that there are some which cannot at present be definitely located, and which thus appear only in the sixth column. From this arrangement, however, local geologists and collectors will perceive that there is still useful information to be obtained about the occurrence of certain species.

The list has been compiled from a number of sources, which are indicated by letters,

C = Common, *i.e.* in most collections.
B = In the collection of the British Museum.
S = In the collections of the Geological Survey.
d = Recorded by Dr. Ch. Barrois in his Recherches sur le terrain Crétacé Supérieur, 1876.
e = In the collection of Mr. J. C. Eccles of Preston and Ventnor.
f = Recorded by Dr. Fitton.
h = In the collection of Mr. J. B. Hue of Ventnor.
i = Recorded by Captain Ibbetson.
k = Collected by Mr. M. Norman for the author, 1880.
n = Recorded by Mr. Norman in Geol. Mag., Dec. 2, Vol. ix. p. 440.
p = Recorded by Mr. C. Parkinson in Quart. Journ. Geol. Soc., Vol. xxxvii. p. 370.

The fossils collected at various times for the Geological Survey have been named by Messrs. Etheridge, Sharman, and Newton. Those under the letters *e*, *h*, and *k* have been determined by myself, and it will be seen that the collections of Messrs. Hue and Eccles contain many species which have not been recorded previously. Our thanks are specially due to these gentlemen for so kindly forwarding their fossils for determination.

List of Fossils from the Passage Beds and Upper Greensand, Isle of Wight.

——	Passage Beds.	Sands and Ragstones.	Freestone.	Chert Beds.	Concretion Beds.	Horizon unknown.	Remarks.
Vertebrata.							
Titanosaurus	–	–	–	–	–	B	
Hylæochelys lata, *Owen.*	–	p	–	–	–	–	
Gyrodus (teeth)	–	n	–	–	–	–	
Lamna (teeth)	–	n	–	–	–	–	
Cephalopoda.							
Ammonites auritus, *Sow.*	–	C	–	–	–	–	
" " var. catillus, *Sow.*	–	C	–	–	–	–	See remarks on p. 443.
" denarius, *Sow.*	–	e	–	–	–	–	
" inflatus, *Sow.* (= rostratus)	–	–	–	–	–	–	
" lævigatus, *Sow.*	–	–	–	–	–	S	
" raulinianus, *d'Orb.*	–	eh	–	–	–	–	
" renauxianus, *d'Orb.*	–	d	–	–	–	–	
" rostratus, *Sow.*	Sh	C	np	–	–	–	
" splendens, *Sow.*	–	n	n	–	–	–	
" varicosus, *Sow.*	–	eh	–	–	–	–	
" sp.	–	–	–	S	–	–	
Anisoceras armatum, *Sow.*	–	d	–	–	–	–	

List of Fossils from the Passage Beds and Upper Greensand—*cont.*

——	Passage Beds.	Sands and Ragstones.	Freestone.	Chert Beds.	Concretion Beds.	Horizon unknown.	Remarks.
Cephalopoda—cont.							
Hamites	–	e	–	–	–	–	
Belemnites minimus ?, *Sow.*	–	h	–	–	h	–	
Nautilus cenomanensis, *Schlüter*	–	–	–	–	–	B	Mentioned in the Brit. Mus. Catalogue of Fossil Cephalopoda.
„ elegans, *Sow.*	–	h	–	p	–	B	
„ expansus, *Sow.*	–	–	–	–	–	B	
„ Fittoni ?, *Sharpe*	–	–	–	–	–	f	
„ undulatus, *Sow.*	–	l	–	–	–	–	
„ sp.	–	–	h	n	–	–	
Gasteropoda.							
Actæon affinis, *Sow.*	–	–	–	–	–	S	
Aporrhais Parkinsoni, *Sow.*	–	eh	–	–	–	S	
Avellana incrassata, *Sow.*	–	eh	–		–	S	
Dentalium decussatum, *Sow.*	–	e	–		–	–	
Fusus	–	–	–		–	S	
Littorina carinata, *Sow.* (in Fitt.)	–	–	–	–	–	S	
Natica Genti, *Sow.* (= gaultina)	–	ehp	–	–	–	–	
Pleurotomaria sp. (with shell)	–	e	–	–	–	–	
Scalaria dupiniana, *d Orb.*	–	e	–	–	–	–	
Solarium conoideum, *Sow.*	–	–	–	–	–	f	[probably a *Pleurotomaria*].
„ ornatum, *Sow.*	–	de	–	–	–	S	
„ (small sp.)	–	e	–	–	–	–	
Trochus	–	–	–	–	–	e	
Turbo problematicus, *P. & R.*	–	–	–	–	–	S	
„ sp.	–	h	–	–	–	–	
Turritella sp. (cast)	–	e	–	–	–	–	
Lamellibranchiata.							
Arca, cf. Carteroni, *d'Orb.*	–	–	–	S	–	–	
„ mailleana, *d'Orb.*	–	–	–	S	–	–	
„ obesa, *P. & Roux.*	–	eh	–	–	–	–	
Anomia	–	e	–	S	–	–	
Avicula (two species)	–	–	–	h	–	–	
Cardita tenuicosta, *Sow.*	–	d	–	–	–	–	
„ sp.	S	–	–	d	–	–	
Cardium gentianum, *Sow.*	–	C	h	–	–	S	
„ hillanum ?, *Sow.*	–	e	–	–	k	–	
„ Constanti ?, *d'Orb.*	–	e	–	–	–	–	
Corbis sp.	–	e	–	–	–	–	
Cucullæa carinata, *Sow.*	h	de	–	–	–	S	
„ glabra ?, *Sow.*	–	dp	–	p	–	–	
Cyprina angulata, *Sow.*	–	–	–	–	–	S	
„ sp.	–	e	–	–	–	S	
Cytherea plana	–	C	–	–	–	S	
„ caperata ?, *Sow.*	–	eh	–	–	–	–	
Exogyra columba, *Sow.*	–	S	–	S	–	–	
„ conica, *Sow.*	–	S	p	p	S	–	
„ digitata, *Sow.* (= laciniata)	–	–	–	–	–	S	
„ haliotoidea, *Sow.*	–	h	–	–	h	–	
„ rauliniana, *d'Orb.*	–	e	–	–	–	–	
Gervillia anceps, *Sow.*	–	e	–	–	–	–	
Inoceramus propinquus, *Goldf.*	–	dh	–	S	–	S	
Isoarca Agassizi ? *P. & R.*	–	e	–	–	–	–	
Lima archiaciana, *d'Orb.*	–	d	–	–	–	–	
„ ornata, *d'Orb.*	–	–	–	p	–	–	
„ semiornata, *d'Orb.*	–	–	–	h	–	–	
„ globosa	–	–	–	–	k	–	
„ rauliniana, *d'Orb.*		e	–	–	–	–	
„ sp. nov. (18 ribs)	–	e	–	h	–	x	In the Museum of the Literary Institute, Ventnor.
„ sp. nov. (38 ribs)	–	h	–	–	–	x	
Modiola reversa, *Sow.*	–	e	–		–	–	
„ ligeriensis ?, *d'Orb.*	–	–	–	–	–	S	
Ostrea canaliculata, *Sow.*	S	C	–	d	–	–	
„ curvirostris ?, *Sow.*	–	h	–		–	–	
„ frons (= carinata)	–	eS	p	–	–	–	
„ virgata, *Goldf.*	–	–	–	–	–	S	
vesicularis, *Lam.*	–	h	–	–	k	–	
„ vesiculosa, *Sow.*	–	Ch	ph	dh	kh	S	
Pecten asper, *Lam.*	–	–	–	S	k	–	
„ Galliennei, *d'Orb.*	–	e	–	S	–	–	
„ hispidus, *Goldf.*	–	d	–	–	–	–	
„ orbicularis, *Sow.*	hS	C	n	Sh	k	–	

List of Fossils from the Passage Beds and Upper Greensand—*cont.*

——	Passage Beds.	Sands and Ragstones.	Freestone.	Chert Beds.	Concretion Beds.	Horizon unknown.	Remarks.
Lamellibranchiata—cont.							
Pecten (Neithea) quadricostatus, *Sow.*	–	C	–	h	k		
„ („) quinquecostatus, *Sow.*	h	Sn	–	S	k	–	
„ („) comata, *d'Orb.*	–	–	–	h	–	–	
Pinna Reyneal, *Heb. & M.*	–	h	–	–	–	–	
„ sp.	S	d	–	–	–	–	
Pleuromya (Panopæa) mandibula, *Sow.*	h	C	–	S	–	S	
„ plicata, *Sow.*	–	np	–	–	–	–	
„ sp.	–	–	–	S	–	–	
Plicatula inflata, *Sow.*	–	–	–	–	k	S	
„ pectinoides, *Sow.*	–	C	h	h	k	–	
„ sigillina, *Woodw.*	–	d	–	–	–	–	
Spondylus striatus, *Sow.*	–	–	–	–	S	–	
Tellina inæqualis, *Phil.*	–	e	–	–	–	–	
Thetis Sowerbyi, *Röm.*	–	eih	–	–	–	S	
Trigonia aliformis, *Park.*	–	C	–	*	–	S	* Mentioned in Lycett's Monograph.
„ carinata, *Ag.*	–	i	–	–	–	S	
„ scabricola, *Lyc.*	–	e	–	–	–	–	
„ spinosa, *Park.*	–	hi	–	–	–	*	* Mentioned by Lycett
„ „ var. subovata, *Lyc.*	–	–	–	–	–	*	* Mentioned by Lycett
„ vicaryana, *Lyc.*	–	p	–	–	–	S	
Venus immersa ?, *Sow.*	–	e	–	–	–	–	
Brachiopoda.							
Crania	–	d	–	–	–	–	
Kingena lima, *Defr.*	–	e	–	–	–	–	
Lingula subovalis, *Dav.*	–	d	–	–	–	–	
Rhynchonella compressa (= dimidiata)	–	–	–	–	–	–	
„ dimidiata, *Sow.*	–	ed	hp	d	–	S	
„ „ var. convexa, *Sow.*	–	p	–	S	–	–	
„ parvirostris ?, *Sow.*	–	e	–	–	–	S	
„ Schlœnbachi, *Dav.*	–	–	h	–	–	x	
Terebratula biplicata, *Sow.*	–	C	he	–	–	–	x Mentioned by Davidson
„ ovata, *Sow.*	–	d	–	–	–	–	
„ phaseolina, *Lam.*	–	–	–	–	–	x	
„ squamosa, *Mant.*	–	–	–	h	–	–	x Mentioned by Davidson
Terebratulina striata	–	h	–	d	–	–	
Terebratella pectita, *Sow.*	–	–	–	–	–	S	
Polyzoa.							
Choriatopetalon impar., *Lons.*	–	–	–	–	–	S	
Ceriopora sp.	–	–	–	–	–	–	
Crustacea.							
Hoploparia Saxbyi	–	n	–	–	–	–	
Annelida.							
Serpula antiquata, *Sow.*	–	C	–	p	–	–	
„ ampullacea, *Sow.*	–	e	–	–	–	–	
„ plexus, *Sow.*	–	h	–	–	–	–	
„ (Vermicularia) concava, *Sow.*	–	C	h	S	hS	–	
„ sp.	–	–	–	S	–	–	
Echinodermata.							
Cardiaster fossarius, *Ben.*	–	?	–	–	k	S	
„ latissimus, *Ag.*	–	–	–	–	–	S	
Catopygus columbarius, *Lam.*	–	–	–	–	–	S	
Discoidea subucula, *Klein*	–	–	–	–	h	–	
Echinospatagus murchisonianus, *Mant.*	–	h	–	h	–	S	
„ Quenstedti, *Wright*	–	e	–	–	–	–	
Hemiaster minimus, *Ag.*	–	e	–	–	–	–	
„ sp.	–	–	–	S	–	S	
Holaster lævis, *de Luc.*	–	en	–	h	k	S	
Spongida.							
Axinella stylus, *Hinde*	–	–	–	x	–	–	x Mentioned by Dr. Hinde.
Doryderma	–	–	–	x	–	–	x Mentioned by Dr. Hinde.
Hetcrostinia obliqua, *Ben.*	–	–	–	–	–	S	
Jerea Websteri, *Sow*	–	n	d	–	–	–	
Siphonia tulipa, *Zittel*	–	ep	–	p	–	–	
Plantæ.							
Clathraria Lyelli, *Mant.*	–	–	n	p	–	–	

CHAPTER X.

GAULT AND UPPER GREENSAND (SELBORNIAN) IN SOUTH DORSET.

General Description.

It will be convenient to describe the Dorset coast after the Isle of Wight, because South Dorset is structurally a continuation of that island, and because Punfield Cove near Swanage is less than 20 miles west of Compton Bay.

In this distance, however, certain changes have taken place. The total thickness of the formation has increased from 132 to 156 feet, yet there is nothing to represent the Chert Beds as distinct from the concretion beds (F), and there is no longer a passage from Greensand to Chalk. At Lulworth, however, sands with true chert set in again and attain a thickness of 9 or 10 feet.

A remarkable point in the stratigraphy of this area is the sudden termination of the Lower Greensand between Mupe Bay and Lulworth Cove.[1] It is difficult to say exactly how it terminates, because in Mupe Bay there is much faulting and crushing out of the Gault and Lower Greensand, while in Lulworth Cove the Gault rests on the Wealden with a marked plane of erosion. Mr. Strahan believes that the Gault becomes unconformable to the Lower Greensand, but it is certain that the Lower Greensand is thinning out westward, and there may not have been much of it left near Lulworth. Whatever explanation is offered, the fact remains that in South Dorset the Gault and Upper Greensand dissociate themselves from the Lower Cretaceous Series, pass across the Wealden Beds, and thence across the outcrops of the successive members of the Upper Jurassic Series.

It is also noteworthy that where the Gault overrides the Lower Greensand on to the Wealden its thickness is locally diminished, as if the Wealden formed a low ridge or bank over which less deposit took place than over those parts of the sea-floor which lay to the east and west of it. Thus in Lulworth and Durdle Coves the total thickness of the formation is only about 130 as compared with 167 at Worbarrow and over 150 at White Nothe.

The impossibility of separating Gault from Upper Greensand in any but a lithological sense is clearly demonstrated in this series of coast-sections. The Gault (clay) is credited with a thickness of 91 feet at Punfield and only about 40 feet at Ringstead Bay, the total thickness of the stage being about the same in each locality; the obvious explanation is that the upper 50 feet of what is called Gault near Swanage has become so sandy at White Nothe that it has been called Greensand at the latter place. Further westward the Gault can no longer be mapped separately from the Upper Greensand, and is included in the Upper Greensand on the maps of the Geological Survey.

How much of this Dorset Gault is Lower Gault belonging to the zones of *Ammonites interruptus* and *Am. lautus* has not been ascertained owing to the obscurity of the sections, the paucity of fossils, and the extreme rarity of Ammonites in the lower beds. It is known, however, that the zone of *Am. interruptus*

[1] *See* Geology of the Isle of Purbeck, Mem. Geol. Survey, by A. Strahan, p. 141 (1898).

exists near Shillington in North Dorset, and we have little doubt that Lower Gault extends at least as far west as Osmington in South Dorset, and probably as far as Seaton in Devon (see p. 188).

The zone of *Ammonites rostratus* occupies as usual the greater part of the combined Gault and Greensand, and Prof. Ch. Barrois has shown that its fauna near Lulworth resembles that of the Blackdown beds.

Stratigraphical Details.

The information in this chapter has been derived chiefly from the memoirs of Prof. Barrois,[1] Mr. Strahan,[2] and Mr. H. G. Fordham.[3] The beds have not been examined personally either by Mr. Hill or myself.

The section in Ballard Hole or Punfield Cove near Swanage was well described by Mr. H. G. Fordham in 1876 and was subsequently measured by Mr. Strahan in 1888. As Mr. Fordham spent several days in measuring the several parts of the Greensand and in collecting its fossils, we shall follow his description in the main; correcting some points, however, by Mr. Strahan's measurements, and adopting his estimate of the total thickness of the stage at this locality. The section is as follows:—

		Ft.	in.
Zone of *Pecten asper.* 10 feet.	Nodular sandstone, consisting of irregular lumps of hard compact sandstone embedded in greenish sand, *Pecten asper*, *Ostrea vesiculosa*, *Ter. pectita*, and other fossils, about	6	0
	Light greensand with a few calcareous concretions - - about	4	0
Zone of *Ammonites rostratus.* 55 feet.	Greensand with scattered fragments of brown phosphate and of broken shells, *Ammonites rostratus* and many *Vermicularia concava*, about - -	14	0
	Dark green sand with three layers of hard sendstone doggers which in places form continuous layers, ?*Rhynchonella convexa*, about - - -	5	0
	Bluish greensand with an irregular layer of stone in the middle, and with rolled phosphatic fossils - - - about	15	0
	Continuous bed of hard stone weathering light blue with white veins -	1	6
	Bluish sandy clay with some hard stony lumps and a continuous bed of hard stone at the base, *Ammonites rostratus*, *Arca carinata*, *Thetis Sowerbyi*, *Dentalium decussatum*, *Vermicularia*, and others -	20	0
Gault -	Bluish-green sandy clay, almost black when wet, passing down into stiffer less sandy clay; very few fossils to be seen. Thickness estimated at - -	91	0
Basement-bed	A thin layer of pebbly sandstone - -	0	4
	Total - - - about	156	0

Here, as in the Isle of Wight, different observers might hold different opinions as to the thickness assignable to the Gault and

[1] Recherches sur le Terrain Crétacé Supérieur, Lille, 1876.
[2] Geology of the Isle of Purbeck, Mem. Geol. Survey, 1898.
[3] Chloritic Marl and Upper Greensand of Swanage Bay, Proc. Geol. Assoc., Vol. iv. p. 506.

to the Greensand respectively. Both Mr. Fordham and Mr. Strahan felt some doubt whether the 20 feet of bluish sandy clay should be classed as Gault or as Greensand. As a matter of fact no such division is possible except in the most general way; the lower clayey part of the stage may be called "Gault," and the upper part is unquestionably "Greensand," but between these two parts is 30 or 40 feet of sandy clay which, so far as lithological character goes, might be classed with either. This sandy clay no doubt corresponds with what Mr. Strahan has very naturally termed the "Passage beds" in the Isle of Wight.

A classification by zones should be more satisfactory, but in consequence of the rarity of fossils in the argillaceous beds we cannot be certain whether the 91 feet classed as "Gault" in the above description is wholly referable to the Lower Gault, or whether some of it belongs really to the Upper Gault (zone of *Ammonites rostratus*). There can be no doubt, however, that the overlying 55 feet belongs to that zone; this part corresponding with the groups B and C of the Compton Bay section, which have about the same thickness.

The two highest beds, which are together less than 10 feet, represent the highest 22½ feet of the Greensand in Compton Bay, and the nodular character of the topmost sandstone suggests that it is the equivalent of the sands with calcareous concretions which occupy a similar position in the Isle of Wight. There is nothing to represent the Chert Beds, which must be regarded as a local development due entirely to the growth and decay of sponges over certain parts of the sea-floor.

Passing across the Isle of Purbeck, a distance of 11 or 12 miles, we come to another complete section in Worbarrow Bay, and the measurements taken by Mr. Strahan show that the total thickness of the stage is somewhat greater there than at Ballard Hole.

Section of Gault and Upper Greensand at Worbarrow Bay.

		Ft.	in.
	Chalk Marl.		
Zone of *Pecten asper* 27 feet.	Sand with irregular lumps of hard calcareous stone	4	8
	Dark greensand, about	3	0
	Lumpy rock, full of *Exogyra conica*, *Pecten asper*, *P. quinquecostatus*, &c.	10	0
	Soft greensand	10	0
Zone of *Ammonites rostratus*, 79 feet.	Soft greensand with layers of calcareous stone in separate blocks, *Vermicularia* and *Ex. conica*	40	0
	Loamy greensand becoming darker below. At the base is a layer of phosphatic fossils, *Natica*, *Pleurotomaria*, *Exogyra conica*, &c.	32	0
	Dark greensand with several layers of calcareous stone	7	0
Lower Gault 64 feet.	Dark-green clayey sand with a few layers of stone, *Lima parallela*, *Pecten orbicularis*, *Natica*, &c.	18	0
	Darker and more clayey micaceous sand or sandy clay, becoming more clayey below	42	0
	Brown sandy clay passing into next	3	0
	Conglomerate of quartzite pebbles in brown clay	1	0
		167	0

The arrangement in zones is my own, and in the absence of recorded fossils from the upper ten feet of soft greensand it is doubtful whether they should be classed in the zone of *Pecten asper* and *Cardiaster fossarius*. In any case, however, this zone is thicker than near Swanage.

It will be noticed that there is also a greater thickness of glauconitic sands, and that stone-beds occur down to a much lower horizon than at Ballard Hole, leaving a much less thickness of sandy clay or "Gault." There is in fact not more than 45 feet which can be called clay, but I have ventured to include the clayey sand with *Lima parallela* as Lower Gault, in the absence of any evidence to the contrary.

The Gault has here a distinct pebbly basement-bed, which is thicker than the similar bed at Ballard Hole, and from this point westward this pebble-bed dissociates itself from the Lower Greensand and clearly belongs to the Upper Cretaceous series, though it varies much in thickness.

A tabular view of this section is given on page 149, and compared with other sections along the south coast.

In Mupe Bay the Upper Greensand is greatly crushed, and portions seem to be faulted out, so that no continuous section of it can be obtained.

Mr. Strahan did not find the section in Lulworth Cove a good one when he saw it, but it seems to have been much clearer in 1875 when examined by Prof. Barrois, who gave a detailed account of it with lists of the fossils which he had collected. The following is a translation of Prof. Barrois' account, but in reversed order and re-numbered:—

		Ft.	*in.*
Zone of *Pecten asper* - 21 feet.	20. Coarse quartzose sandstone with some glauconite grains, passing down into white fine-grained sandstone with little glauconite, containing layers of chert	11	6
	19. Greensand with phosphatised fossils, *Pecten asper* - -	1	6
	18. Glauconitic calcareous sandstone	1	6
	17. Marly greensand, with *Pecten asper* and many phosphatic fossils -	6	6
Zone of *Ammonites rostratus* - 92½ feet.	16. Calcareo-siliceous sandstone - -	1	0
	15. Greensand - - - - -	1	6
	14. Calcareo - siliceous sandstone, with pitted surface - - -	3	3
	13. Greensand with *Vermicularia concava*, and *Ostrea* - - - -	5	0
	12. Calcareous sandstone with large grains of glauconite, many *Janira 4-costata* of large size - - - -	3	3
	11. Sand with a bed of *Ostrea vesiculosa* at the base and some fossils in phosphate of lime - - - -	6	6
	10. Sandstone with *Serpulæ* - - -	0	8
	9. Greensand, including a layer of small oysters with some phosphatic nodules	8	6
	8. Nodules of calcareous sandstone in a discontinuous layer; numerous fossils	1	6
	7. Greyish-black micaceous sand, with gypsum, pyrites, and thin layers of phosphatic fossils - - - - -	6	6

		Ft.	in.
Zone of *Ammonites rostratus*—cont.	6. Greenish-grey sandstone, *Vermicularia concava*, *Janira 4-costata*	0	6
	5. Greensand poor in fossils	30	0
	4. Greyish stone, *Vermicularia concava*, *Exogyra conica*	1	6
	3. Sand	6	6
	2. Soft argillaceous and micaceous sand-rock	1	6
	1. Black sandy clay (Gault), seen for	15	0
		113	8

Here also estimates of the thickness of the Gault have varied. Fitton made the total thickness 142 feet, assigning 66 to the Gault and 76 to the Greensand.[1] Barrois, in the section above quoted, makes the Greensand about 99 feet, which, if Fitton's total were correct, would leave 43 to the Gault; but according to Mr. Strahan's measurement the thickness of the clayey part is not more than 28 feet, and that of the Greensand without the topmost bed is 101 feet; if this top bed (about 6 feet) is added we have a total of 135 feet.

In Durdle Cove there is a good exposure of the upper beds, which are described by Mr. Strahan as follows[2]:—

	Feet.
Hard white calcareous sandstone	3
Greensand with lumps of hard white stone	3
Hardened sand with nodules of chert and irregular masses of chert in the lower 2 feet	6
Dark green loamy sand	1
Greensand with chert	2
Dark greensand with 3 or 4 bands of cherty stone, *Exogyra conica* and *Pecten* (*Neithea*) *5-costatus* abundant	7
Greensand with very lumpy cherts	2
	24

The section is continued in Man of War's Cove, which shows 84 feet of greensand getting darker and more loamy below, at the bottom of which is a conspicuous ferruginous band about a foot thick; below this is 22 feet of dark-blue sandy clay with a thin pebble-bed at the base consisting of quartz pebbles from the size of a pea up to 2 inches long. This rests on Wealden Beds with a marked plane of erosion.

Here also, then, the beds referable to the Gault do not exceed 24 feet in thickness; the zone of *Am. rostratus* is 84 feet, and the zone of *Pecten asper* is 24 feet. Total about 132 feet.

Two miles further west, at White Nothe, Mr. Strahan was again able to measure sections which show a thickness of more than 160 feet, an increase of 18 feet. Combining the section at White Nothe itself, where the upper beds are well seen, with that

[1] Trans. Geol. Soc., Ser. 2, Vol. iv. p. 216.
[2] Geology of the I. of Purbeck and Weymouth, p. 153.

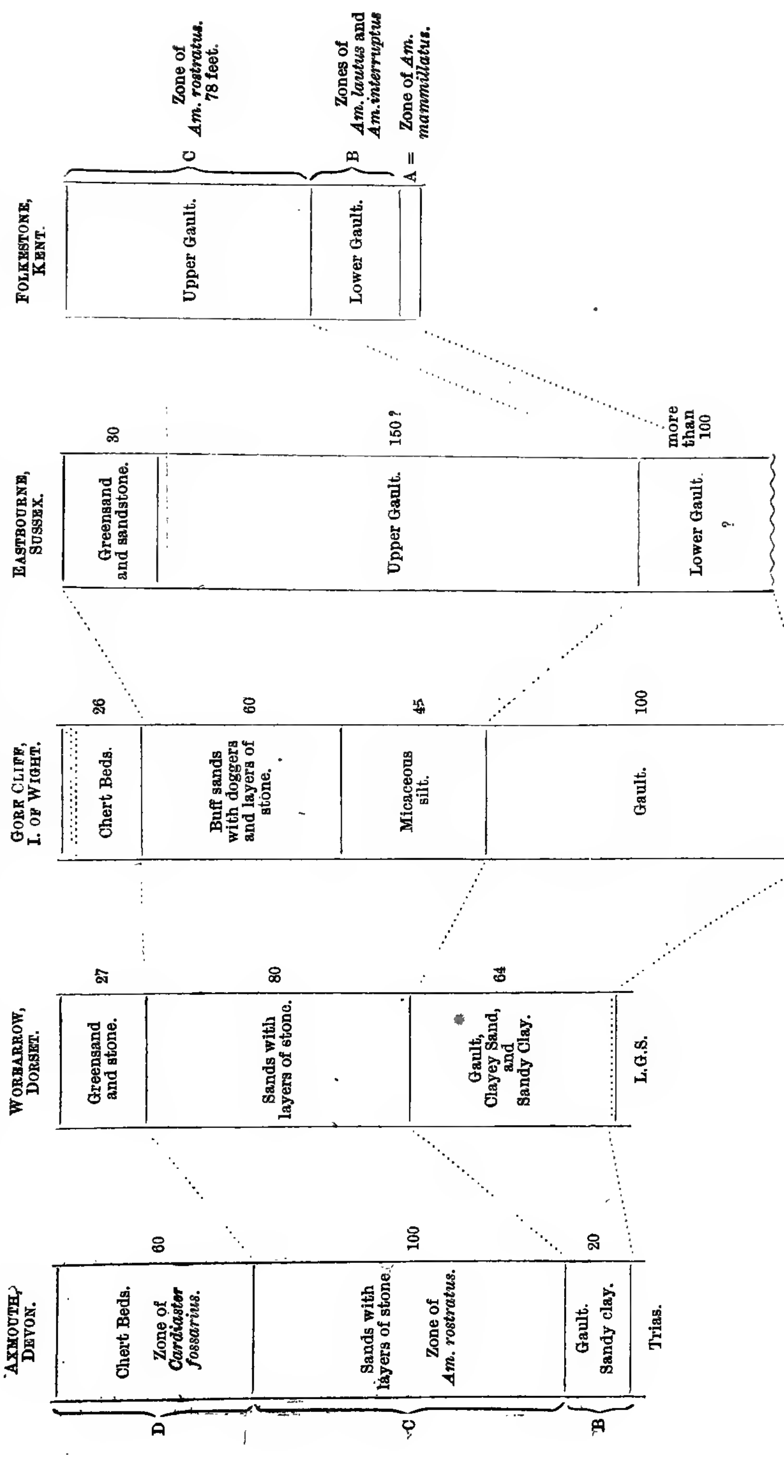
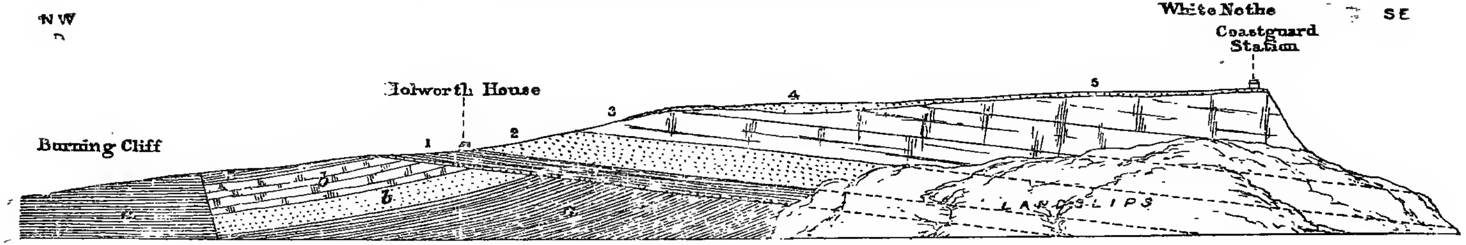


FIG. 57.—COMPARATIVE SECTIONS OF THE GAULT AND UPPER GREENSAND ALONG THE SOUTH COAST.
Scale 60 feet to one inch.

FIG. 58.—*Section through Holworth House and White Nothe, Dorset* (A. STRAHAN).[1]

Scale, horizontal and vertical, 12 inches to a mile, or 440 feet to an inch.



5. Upper Chalk.
4. Middle Chalk.
3. Lower Chalk.
2. Upper Greensand.
1. Gault.

c. Purbeck Beds.
b. Portland Beds.
a. Kimeridge Clay.

[1] Geology of the Isle of Purbeck and Weymouth, Plate IX. (See also p. 156.)

visible east of Holworth House, the succession appears to be as follows:—

		Ft.	in.
Sands with *Pecten asper*, 19 ft.	Hard nodular calcareous sandstone -	6	0
	Sand with nodules of chert -	3	0
	Sand with two layers and nodules of chert -	4	6
	Dark greensand with cherty lumps, *Pecten asper*	6	4
Zone of *Ammonites rostratus* over 100 feet.	Dark greensand with three layers of stone -	19	0
	Similar sand with scattered lumps of stone	13	6
	Irregular layer of stone with *Exogyra conica*	11	0
	Dark-green loamy sand with pipings of clay	25	0
	Great lenticular stone masses - - -	2	0
	Dark greensand - - -	13	6
	Lenticular masses of stone - -	1	6
	Dark greensand, base not seen - -	13	6
	Gap.	?	
Gault -	Dark loamy and clayey sand and clay, about -	36	0
	Blue sandy micaceous clay - - - - -	4	0
	Thin layer containing quartzite pebbles and lumps of Portland stone - -	1	1
Kimeridge Clay.			
		159	0

Mr. Strahan does not give any estimate of the thickness covered by the "gap," but it is evident that the total thickness must be considerably over 160 feet. Mr. Rhodes collected many fossils from this locality, which were identified by Mr. Sharman and are embodied in the list at the end of this chapter.

Mr. Strahan remarks that the section in the cliff at Holworth House gives a magnificent view of the base of the Upper Cretaceous series and of its unconformable superposition to the Jurassic rocks. "The junction can be identified at once in the brow of the cliff at Holworth House, where Gault dipping E.N.E. at 5° passes in quick succession across the edges of Purbeck, Portlandian, and Kimmeridge Clay, dipping north at 25°. Thence it can be followed for about 600 yards southwards, though it becomes less conspicuous from the fact that the Gault Clay there rests upon Kimmeridge Clay." (Op. cit., p. 155).

The accompanying view and section, both reproduced from Mr. Strahan's Memoir, illustrate the position of the strata at this interesting locality. In the view (Fig. 59) the rocks in the left-hand corner are Portlandian, with Gault resting nearly horizontally upon them. The cliffs above show Greensand and Chalk, and the furthest point seen is White Nothe, with its undercliff of slipped masses of Greensand and Chalk.

The following notes are also quoted from Mr. Strahan's Memoir:—"In the tract between White Nothe and Osmington Mills the Upper Cretaceous rocks are thrown on end by the Ringstead disturbance. . . . But the unconformity at the base of the Gault is again finely exposed for about 50 yards in the brow of the cliff, 300 yards west of Osmington Mills. The Kimeridge Clay dips north at 40°, but the Gault lies horizontally upon it, its base being a loamy buff-coloured sand with an occasional quartz-pebble. In the hill above the whole of the Gault and Greensand are represented, together with the lowest beds of the Chalk, but the last-named has been almost completely decalcified and has mouldered down into a yellow sandy clay."

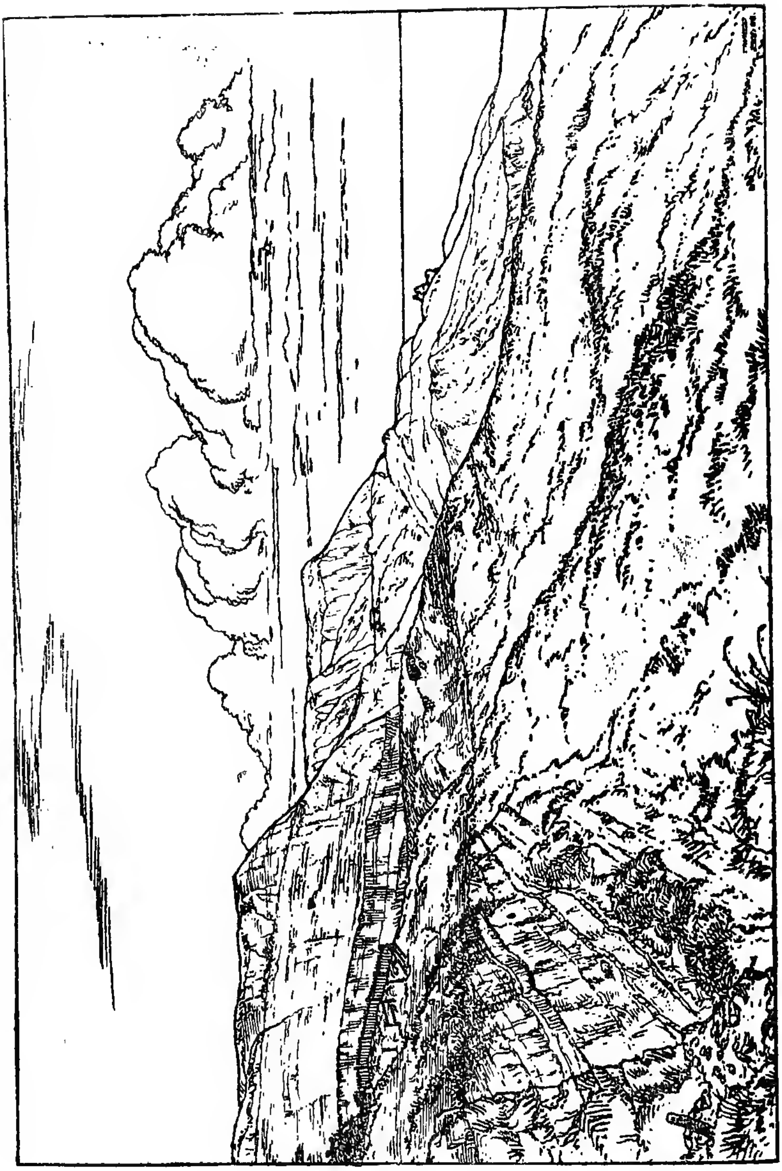


FIG. 59.—*View at White Nothe, Dorset, showing the unconformity between Cretaceous and Jurassic Rocks.*

(Drawn by H. W. Gilbert Williams from a photograph.)

From A. Strahan's Memoir on the Geology of the Isle of Purbeck, p. 156.

"The outcrop of the Upper Greensand and Gault along the great Ridgeway disturbance [from Chaldon to Bincombe] is interesting chiefly from the light it throws on the structure [of the country]." South-west of Bincombe church there is a section exposing about 84 feet of the green sand from the summit downwards, the beds here having a northerly dip of 45° to 50°.

West of the Dorchester and Weymouth railway the whole formation is cut out by the thrust of the Ridgeway fault, and is not seen again till it comes in as a regular outcrop north of Abbotsbury. This tract will be described later on under the head of West Dorset.

List of Fossils from the Gault and Upper Greensand of the Dorset Coast.

This list of fossils has been compiled from the following sources:—Mr. H. G. Fordham for the Swanage or Ballard Hole section; Prof. Barrois for the sections at Worbarrow, Lulworth, and Durdle Coves; the collections of the Geological Survey at White Nothe and Ringstead Bay, supplemented by a few mentioned by Prof. Barrois; Mr. Damon's list of fossils from the cliff west of Osmington Mills, supplemented by specimens in the Dorchester Museum and in that of the Geological Survey.

For these localities the following letters are used:—

s = Swanage.
w = Worbarrow Cove.
l = Lulworth and Durdle Coves.
n = White Nothe and Ringstead.
o = near Osmington.

The first column shows the fossils found in those beds which we have classed as Lower Gault. The second contains the fossils obtained from the lower sands and stone beds, and principally from the bed numbered 8 in Prof. Barrois' section (p. 147). These belong to the lower part of *Am. rostratus* zone. Those from the upper part of this zone are entered in column 3; and in column 4 are the species found in the very highest beds which form the zone of *Pecten asper* and *Cardiaster fossarius*.

———	Gault.	Ammonites rostratus zone.		Pecten asper zone.
	1.	2.	3.	4.
Lamna appendiculata, *Ag.*	–	–	–	w
Cephalopoda.				
Ammonites Mantelli, *Sow.*	–	–	–	w
" Goodhalli, *Sow.*	–	l	–	–
" raulinianus, *d'Orb.*	–	l	–	–
" rostratus, *Sow.*	–	s l	–	–
" splendens ?, *Sow.*	–	l	–	–
" varicosus ?, *Sow.*		l	–	–
" (several sp.)	–	o	–	–
Ancyloceras sp.	–	–	–	l
Belemnitella sp.	–	–		n
Hamites alternatus, *Mant.*	–	l	–	–
" virgulatus, *Brong.*	–	l		
" sp.	–		–	n
Nautilus	–	–		n
Scaphites æqualis, *Sow.*	–	–		l

	Gault. 1.	Ammonites rostratus zone. 2.	3.	Pecten asper zone. 4
Gasteropoda.				
Aporrhais Parkinsoni, *Sow.*	–	l	–	–
,, sp.	–	–	–	l
Avellana cassis, *d'Orb.*	–	–	–	l
Dentalium decussatum, *Sow.*	l n	s	–	–
Natica Genti, *Sow.*	–	-	–	n
Turbo	–	n	–	–
Turritella costata, *Sow.*	l n	–	–	–
,, granulata ?, *Sow.*	–	o	–	–
,, sp.	–	n	–	
Lamellibranchiata.				
Astarte concinna, *Sow.*	–	l	–	
,, impolita, *Sow.*	–	l o		
,, striata, *Sow.*	–	l		
Arca (Cucullæa) æquilateralis, *C. & Briart*	–	l	–	
,, ,, carinata, *Sow.*	l	s l	s	–
,, ,, echinata, *d'Orb.*	–	–	–	l
,, ,, glabra, *Park.*	n	s l n o	s	s n
,, ,, mailleana, *d'Orb.*	–	s (?)	–	l
,, ,, nana, *d'Orb.*	–	l	–	–
,, ,, obesa, *P. & Rx.*	–	l	–	–
,, ,, passyana, *d'Orb.*	–	–	–	l
,, ,, sp.	n	–	–	–
Cardium hillanum, *Sow.*	–	o	–	–
,, ventricosum, *d'Orb.*	–	–	–	l
Cardita dubia, *d'Orb.*	–	–	–	l
,, dupiniana, *d'Orb.*	–	l	–	–
,, sp.	l	–	–	–
Cyprina consobrina, *d'Orb.*	–	–	–	l
Cytherea caperata, *Sow.*	–	l n	–	–
,, parva, *Sow.*	–	l	–	–
,, plana, *Sow.*	–	n o	–	–
,, subrotunda, *Sow.*	–	l	–	–
Exogyra columba, *Sow.*	–	l o	s	s w
,, conica, *Sow.*	n (?)	s l o	s l	s w l n
,, haliotoidea, *Sow.*	–	–	s	s
Inoceramus concentricus, *Park.*	–	o	–	–
,, sulcatus, *Park.*	–	l	–	–
,, sp., (cf. Crispi, *Mant.*)	–	o	–	–
Lima archiaciana, *C. & Br.*	–	–	–	l
,, astieriana, *d'Orb.*	–	–	–	l
,, parallela, *d'Orb.* (non *Sow.*)	l w n	–	–	–
Limopsis Lorioli ?, *Renv.*	–	l	–	–
Lucina lenticularis ? *Goldf.*	–	o	–	–
Mactra angulata, *Sow.*	–	l	–	–
Modiola reversa, *Sow.*	–	l	–	
,, sp.	–	o	–	
Nucula pectinata, *Sow.*	n	–	–	–
,, (cast, cf. lineata, *Sow.*)	–	l	–	
,, (cast, cf. bivirgata, *Sow.*)	–	l	–	
Ostrea canaliculata, *Sow.*	–	s l	–	s
,, frons, *Park.* (= carinata)	–	–	–	l
,, vesiculosa, *Sow.*	–	l	s l	s l
,, vesicularis (?), *Lam.*	–	s	s	

——	Gault. 1.	Ammonites rostratus zone. 2.	3.	Pecten asper zone. 4.
Lamellibranchiata—cont.				
Pecten asper, *Lam.*	–	–	–	s w l n o
„ elongatus, *Lam.*	–	–	–	l
„ Galliennei, *d'Orb.*	–	s l	s	s
„ hispidus, *Goldf.*	–	–	l	l
„ Milleri, *Sow.*	–	l	–	–
„ orbicularis, *Sow.*	n	s l o	s l	s n
„ (Neithea) æquicostatus, *d'Orb.*	–	l	–	–
„ „ alpinus, *d'Orb.*	–	o	–	–
„ „ 4-costatus, *Sow.*	–	s l n	s l	s w l n
„ „ 5-costatus, *Sow.*	–	l	–	w l n
Pectunculus umbonatus, *Sow.*	–	o	–	–
Pinna tetragona, *Sow.*	l n	–	–	–
Pleuromya (Panopea) læviuscula, *Sow.*	–	–	s l	–
„ „ plicata, *Sow.*	l n	s n o	–	s
„ „ Rhodani, *P. & Rx.*	–	l	–	–
Plicatula pectinoides, *Sow.*	–	s	s l	–
Siliqua moreana ?, *d'Orb.*	–	l	–	–
Spondylus ? occultus, *Gein.*	–	–	–	l
„ Omalii, *d'Arch.*	–	–	–	l
Thetis Sowerbyi, *Röm.*	–	s l n	–	–
„ genevensis, *P. & Rx.*	–	l	–	–
Trigonia aliformis, *Park.*	–	l o	–	–
„ scabricola, *Lyc.*	–	l	–	l n
„ spinosa, *Park.* (including pyrrha, *d'Orb.*)	n	l	–	–
„ sp.	–	s n	–	–
„ new sp.	–	l	–	–
Venus faba, *Sow.*	–	l	–	–
„ immersa, *Sow.*	–	l	–	–
„ rotomagensis, *d'Orb.*	–	–	–	l
„ truncata, *Sow.*	–	l	–	–
„ submersa, *Sow.*	–	l	–	–
„ (several species)	–	o	–	–
Brachiopoda.				
Rhynchonella dimidiata, var. convexa, *Sow.*	–	–	s	–
„ sp.	–	–	–	l
Terebratella pectita, *Sow.*	–	–	–	s w l
Terebratulina triangularis, *Eth.*	–	–	–	l
Annelida.				
Ditrupa difformis, *Sow.*	–	–	–	l
Serpula antiquata, *Sow.*	–	–	s	n
„ gordialis, *Schl.*	–	–	–	l
„ ilium, *Sow.*	–	–	–	n
„ tuba, *Sow.*	–	–	s	w
„ (Vermicularia) concava, *Sow.*	n	s l n o	s w l	s l n
„ „ polygonalis, *Sow.*	–	l	–	–
Echinodermata.				
Caratomus rostratus, *Ag.*	–	–	–	l
Cardiaster latissimus, *Ag.*	–	o	–	–
fossarius, *Benett*	–	–	–	l

	Gault. 1.	Ammonites rostratus zone. 2.	3.	Pecten asper zone. 4.
Echinodermata—cont.				
Catopygus columbarius, *Lam.*	–	–	–	l
Cidaris velifera, *Bronn.* - -	–	–	l ?	l
„ vesiculosa, *Goldf.* - -	–	–	–	l
Discoidea subucula, *Klein.* -	–	–	–	l n
Glyphocyphus radiatus, *Desor.*	–	–	–	l
Holaster lævis, *de Luc.* (=carinatus)-	–	–	–	l n
„ Brongniarti ?, *Heb.* -	–	–	–	l
„ suborbicularis ?, *Defr.* -	–	–	–	l
Peltastes clathratus, *Ag.* - - -	–	–	–	l
Pseudodiadema variolare, *Ag.* - -	–	–	–	n
„ ornatum, *Goldf.* -	–	–	–	n
„ sp. -	–	l		

CHAPTER XI.

GAULT AND UPPER GREENSAND (SELBORNIAN) IN NORTH DORSET.

Before dealing with the Selbornian deposits in West Dorset and Devon it will be desirable to describe those of North Dorset, taking a fresh starting-point on the borders of Wilts and Dorset, and tracing the outcrop of the formation from thence through the northern and western parts of the county.

The surface area of the Selbornian in North Dorset is divided naturally into two portions by the valley of the Stour, and it will be convenient to describe these separately, taking first the tract between Shaftesbury and the river Stour, and then that between the Stour and Evershot near the head waters of the Frome.

1. Shaftesbury to the River Stour.

The southern border of the Vale of Wardour ends in a high plateau of Greensand from 700 to 800 feet above the sea, and where this bends southwards is situate the ancient town of Shaftesbury. Thence the outcrops of the Gault and Greensand run southward to the valley of the Stour near Child Okeford.

The Gault at Shaftesbury is probably about 90 feet thick. As in Wiltshire the whole of this belongs to the Lower Gault. This Gault does not thin out suddenly south of Shaftesbury as shown on the old Geological Survey map, but is continuous southward and maintains a fair thickness to and beyond the valley of the Stour.

The Upper Greensand near Shaftesbury is about 150 feet thick and presents the same succession of beds as in the Vale of Wardour, this succession being as follows:—

		Feet.
Fine greensand	about	10
Chert beds	„	20
Coarse glauconitic sandstone	„	10
Soft grey and buff sands	„	70
Micaceous sand and sandstone	„	40

But as the outcrop of these beds is followed southward it changes rapidly and loses greatly in thickness. In the first place the malmstone and micaceous sandstone either thin out or pass into a smaller thickness of soft micaceous sand. At the same time the hard glauconitic sandstone which forms such a conspicuous feature in the Vale of Wardour and near Shaftesbury gradually thins out. The Chert Beds also disappear to the south of Melbury, so that there are then no hard beds to form an escarpment like those of the Vale of Wardour. The beds which

remain are soft grey and green sands, and these form a gentle and almost featureless slope up from the Gault to the base of the chalk. The total thickness of these sands near Iwerne Minster and Shroton is not more than 50 or 60 feet, less than half the thickness of the Greensand near Shaftesbury.

Gault.

From Shaftesbury the Gault can be traced southward as a continuous band of yellow brown and grey micaceous clays below the escarpment of the micaceous sands, this micaceous character distinguishing it from the shaly and non-micaceous Kimeridge clay on which it rests. Moreover, from Twyford to the valley of the Stour the boundary of the Gault is defined by the outcrop of the Lower Greensand, which here emerges from beneath it.

The Gault clays are exposed in a brickyard at Sutton Waldron, and in another west of Iwerne Minster. At the former the following beds were seen in 1891 :—

	Ft.	in.
Grey and brown sandy micaceous clay	5	0
Layer of loose red and brown ferruginous rubble	0	4
Grey and light brown mottled clay, with patches of yellow micaceous sand and green glauconitic sand	2	0
Dark reddish-brown micaceous and sandy clay with many phosphatic septaria	1	6
Dark greenish-grey sandy clay	2	0
Tough brown clay	0	9
Dark grey sandy loam, dug into for	2	6
	14	0

The same layer of red-brown hæmatitic ferruginous rubble is shown in the Iwerne Minster brickyard, and the foreman stated that a well was sunk through 30 feet of dark grey sandy clay underneath this "red layer," a bed of hard dark grey rock being found about 10 feet down.

Fossils are very rare in this Dorsetshire Gault; the small Belemnites so common in Gault elsewhere being entirely absent, but small oysters and "snake-stones" (Ammonites) are reported to occur occasionally by the workmen.

A boring made at Fontmell Brewery in 1887 is said to have been carried through 150 feet of clay into coarse sand with water, but this may have passed through a fault plane, for the Gault is certainly less than 100 feet thick at its outcrop, and a little further south, near Child Okeford, it is not more than 70 feet.

Upper Greensand.

Zones of Ammonites rostratus and Pecten asper.

Most of the older quarries at and near Shaftesbury are no longer worked, and are quite overgrown, and little can be seen in the road cuttings north of the town; but south-east of the town by Boyne Hollow two quarries show good sections of the Chert Beds and the road descending to Melbury exposes a good downward

succession. Finally another quarry west of Melbury shows the junction with the Chloritic Marl. Combining these exposures the complete succession of beds near Shaftesbury appears to be as follows:—

		Feet
Zone of Pecten asper	Fine-grained glauconitic sandstone -	10
	Chert Beds and sands, with siliceous concretions over	20
	Coarse glauconitic sandstone about	10
Zone of Am. rostratus -	Soft greenish-grey sands "	70
	Buff micaceous sand and sandstone "	20
	Tough grey micaceous sandstone becoming dark and argillaceous below - -	15 to 20
		about 150

The higher beds present some interesting features and several of the sections are so good as to merit special description. The first of these is a quarry at the northern end of Boyne Hollow, where the following section was seen by Mr. Hill in 1897:—

	Ft.	in.
Soil and rubble - - - - - - - - - -	1	6
Rather soft pale grey sandy stone, with siliceous cherty concretions - - - - - - - - -	3	6
Soft grey glauconitic sand with smaller concretions -	4	6
Layer of brown siliceo-phosphatic masses - - - - -	0	9
Firm grey glauconitic silty sand - - - -	2	0
Fine greyish sandstone, firm but not hard, with grey cherty concretions - - - - - - - - -	3	6
Pale whitish-grey powdery sandstone, full of hard calcareo-siliceous concretions, some of which have centres of blue-grey chert - - - - - - - - - -	4	0
Massive layer of blue-grey chert with thick whitish rind -	1	0
Firm grey glauconitic sand. with a layer of small brownish concretions at the base - - - -	1	3
Greenish-grey very glauconitic sandy rock with a few brown phosphates - - - - - - - - -	2	0
Very hard glauconitic semi-crystalline sandstone, called "Rag"; many fossils at the top - - - - - -	3	0
Softer but firm compact glauconitic sandstone with calcite cement - - - - - - - - -	4	6
Soft greenish-grey glauconitic sand, seen for - -	2	0
	33	6

The hard sandstone known as *Rag* is used for road metal, and the better stone below is used for building-purposes. This sandstone has been quarried extensively south of Shaftesbury, and the old overgrown excavations are now as "The Wilderness." More recently it has been dug for road-metal on Cann Common by the side of the road leading to Melbury. The outcrop of it is exposed in the cutting on the same road two miles from

Shaftesbury, and at Melbury below the church, and it has been quarried to the west of Melbury Hill. In this quarry the following beds are seen dipping about 5° to the E.S.E.:—

	Feet.
Soft porous and light-coloured stone with lenticular layers of black chert and large nodules of a brownish fine-grained calcareous sandstone - - - -	5
Soft grey glauconitic sand with scattered phosphates and a few concretions of pinkish glauconitic sandstone (2 feet) passing down into rubbly sand full of oysters and Pectens and broken phosphatic nodules, 9 to 12 inches; the base uneven -	3
Massive bed of glauconitic calcareous sandstone with many open joints, passing into next	3
Firm sand rock, without calcareous cement	6

The following fossils were found by Mr. Rhodes and myself in the 3 feet of grey sand:—

Discoidea subucula.
Peltastes clathratus.
Pseudodiadema ornatum.
Serpula (V.) concava.
Rhynchonella dimidiata.
Terebratula ovata.
Astarte (cast).
Exogyra conica.
Ostrea vesiculosa.
Pecten asper.
„ Galliennei.
„ orbicularis.
„ (Neithea) cometa.
„ „ quadricostatus.
„ „ quinquecostatus.
Trigonia carinata.
Avellana incrassata.
Belemnites sp.
Nautilus lævigatus.

North of the quarry is a small exposure in a bank at a rather higher level, showing soft greenish-grey sandstone containing *Pecten orbicularis, P. (Neithea) quadricostatus, Exogyra conica, E. columba* and *Trigonia carinata.*

The highest member of the Greensand, and the upward succession through Chloritic Marl and Chalk Marl is well exposed in a quarry on the north side of Melbury Hill, where the following notes were written in 1892:—

		Feet.
Chalk Marl	6. Greyish marly chalk - - - - - -	6
	5. Grey marly and and sandy chalk - -	$4\frac{1}{2}$
	4. Firm glauconitic chalk, rather hard for the most part but shaly at the base - - -	$2\frac{1}{2}$
	3. Chalky glauconitic sandstone, drying to a light greenish grey, with many fossils - -	4
Upper Greensand	2. Rough glauconitic sandstone, with iron stains and patches of hard brown material like impure chert: many broken shells and small phosphatic nodules weather out - -	4
	1. Softer fine grained greenish glauconitic sandstone with few fossils, seen for -	6

Bed 1 is a freestone, and is used for building-stone, and 2 for rough work. All the beds pass into one another, and it is not easy to say where the dividing line between Chalk and Greensand should be drawn, but No. 2 is unquestionably a part of the sandstone below, and is a sandstone with little or no chalky matter, whereas No. 3 has a considerable admixture of

such material, and moreover contains the usual fossils of the Chloritic Marl. From No. 2 the Survey collector obtained the following fossils:—

Serpula (Vermicularia) concava.
Catopygus columbarius.
Holaster subglobosus. ?
Rhynchonella dimidiata.
Terebratula biplicata.
" ovata.
Terebratulina striata.
Inoceramus (like mytiloides).
Pecten asper.
" hispidus.
" orbicularis.
Neithea quinquecostata.
Plicatula inflata.
Pleurotomaria sp.
Ammonites Mantelli.
Ancyloceras ? (fragment).
Turrilites Bechei.

When the sands and sandstones are traced southward from Melbury considerable changes are found to take place, the malmstone and micaceous sandstone pass first into soft grey argillaceous sandstone, with thin lumpy layers of harder micaceous sandstone, and finally into a soft sandy micaceous marl which no longer makes a definite feature. The lumpy beds were seen in an excavation for a gate-post at Fontmell Magna in 1891, and yielded *Arca* (*Cucullæa*) *carinata*, *Cytherea plana*, *Pecten orbicularis* and other Devizes fossils.

The middle beds of the Greensand, soft yellowish green and grey sands with large burr-stones of fine-grained calcareous sandstone are exposed in a sand pit east of the church at West Compton, and in another pit north of Iwerne Minster Park. The higher greenish-grey sands are dug in a pit east of Sutton Waldron, and a little further up the lane at a level only 12 feet higher and very near the base of the Chalk a bed of hard glauconitic sandstone crosses the road.

A similar succession is found further south, between Shroton and Child Okeford, 15 feet of greensand with a few large burr-stones being exposed in a sand pit a little above which at the entrance to "Sandy Lane" a bed of hard glauconitic sandstone crops out. In the field above this lumps of hard glauconitic marlstone lie about just below the boundary of the Chalk.

2. Valley of the Stour to Evershot.

Near Shillingstone on the Stour the strike of the Cretaceous rocks changes its direction again, and the general direction of the outcrops is westward for some distance, the dip being southward under the great synclinal trough of South Dorset.

The Gault continues to occupy its usual position and to maintain a fair thickness for some distance, but towards Evershot it either thins out or becomes so sandy as to be indistinguishable from the lower part of what has been called Upper Greensand. The zones of *Amm. mammillatus* and of *Am. interruptus* have been identified at Okeford Fitzpaine.

The Greensand varies somewhat in thickness along the outcrop, being from 60 to 70 feet, near Okeford, it thins to less than 60 near Buckland, but increases again westward. The greater part of it

belongs to the zone of *Ammonites rostratus*, consisting mainly of soft sands with occasional calcareous doggers, but towards the west a bed of rubbly glauconitic sandstone comes in at the top.

The zone of *Pecten asper* and *Cardiaster fossarius* is thin, being nowhere more than 10 feet thick. Through the greater part of the tract it consists of soft green sand in the lower part which passes up into a hard calcareous glauconitic stone, the upper part of which is for some distance a conglomerate of brown phosphatic nodules and fossils, the fauna being an interesting one.

Gault.

Between Shillingstone and Okeford Fitzpaine the Gault appears to be about 60 feet thick, and its sandy glauconitic clays are easily distinguishable from the dark shaly Kimeridge clays on which it here rests. A good section of the lower part of the Gault is found in the brickyard near Okeford Fitzpaine; about 16 feet were visible here in 1891, and the foreman stated that about 2 feet lower the clay rested on a thick bed of dark brown sandy ironstone, which broke into large blocks. He had made a trial excavation below this stone, and the following account is partly compiled from the information obtained from him, confirmed by samples of sand and ironstone still lying in the pit[1]:—

		Feet.
Zone of *Ammonites interruptus*	Light grey clay containing grains of glauconite	7
	Dark grey sandy micaceous clay with nests or patches of glauconitic sand, about	11
	Dark brown sandy ironstone - -	4
Zone of *Am. mammillatus*	Bluish sand with many small pebbles - -	4
	Brown sandy ironstone, breaking into small lumps	1½
Lower Greensand	Clean green sand - - - - - - -	1
Kimeridge Clay	Strong blue clay with a hard rock at depth of -	8

In 1896 Mr. R. B. Newton gave an account of this section, and of the fossils found in it by Miss Forbes of Shillingstone House, and Miss Lowndes. The lower part of the section was measured by these ladies, and the particulars given by them do not differ materially from those given to me, except that they found the green sand at the base to be 3 feet thick. Fortunately, however, they obtained fossils both from the sandy beds and from the base of the overlying sandy clay; and it was from the evidence of these fossils that Mr. R. B. Newton was able to recognise the existence of the zone of *Am. mammillatus* at this place, as well as the overlying zone of *Am. interruptus*. In grouping the beds, I have followed Mr. Newton, who says that the 4-foot bed of sandy ironstone contained "a Lower Gault fauna," though he does not give a separate list of the fossils found in it.

[1] See "Geol. Mag.," 1896, p. 198, and Proc. Dorset Nat. Hist., and Ant. Field Club, vol. xviii., p. 66 (1897).

Fossils were obtained from this ironstone, from the lower four feet of the clay, and the species determined were :—

Lamna appendiculata.
Synechodus sp.
Ammonites interruptus.
„ splendens.
Hamites sp.
Nautilus clementinus.
Actæonina formosa.
Ringinella inflata.
Aporrhais carinata.
Natica Genti (= gaultina).
Scala dupiniana.
Solarium ornatum.
Cucullæa [Arca] carinata.
Gervillia forbesiana.
Inoceramus concentricus.
Lima parallela (common).
Mytilus subsimplex.
Nucula pectinata.
Exogyra canaliculata.
Pecten orbicularis.
„ Galliennei.
Pholadomya favrina.
Pleuromya plicata.
Solen dupinianus.
Thracia new sp.
Teredo.
Trigonia aliformis.
„ archiaciana.
„ Fittoni.

The following is a list of fossils from the lower beds, as recorded by Mr. Newton:—

Ammonites mammillatus.
„ benettianus.
Cucullæa [Arca] carinata.
Exogyra sinuata.
Ostrea Leymerii.
Pleuromya plicata.

He describes the matrix surrounding these shells as "mostly of an argillaceous sandy character, slightly micaceous, and of a brown grey or yellowish colour. That associated more particularly with the specimens of Ostrea and Exogyra exhibits an oolitic structure, the grains of which are heavily charged with hydrated oxide of iron." In the account published by him the lower bed of ironstone is not separated from the argillaceous sand above. If the foreman's account is correct, and if the Ammonites are confined to the fine sandy bed, it is possible that the oolitic ironstone should be grouped with the Lower Greensand and not with the Gault.

The outcrop of the Gault was mapped by me as far as Ibberton, and another portion near Melcombe Bingham was mapped by Mr. Reid in 1895, but beyond that the country has not yet been continuously re-surveyed. In 1892, however, Mr. Whitaker made a reconnaissance along this tract, and obtained information regarding the Gault, from which the following account has been drawn up. The writer subsequently examined the district near and north of Cerne Abbas.

The Gault appears to be present continuously below the Greensand; a brickyard at Lower Anstey shows a stiff loamy clay with nests of glauconitic sand, and below this is a soft dark grey micaceous sand or silt like that seen at Okeford brickyard.

About two miles further west, near Armswell Farm, is an old pit showing brown sandy clay, very hard and ferruginous at the bottom, this being probably close to the base of the Gault.

Grey sandy and micaceous clay can be traced all round the outlier of Greensand and Chalk forming Dungeon Hill, north of Buckland Newton.

At Lyons Gate, north of Minterne, within the area coloured as Coral Rag on the old Geological survey map, is a brickyard, the upper level of which shows six feet of grey and brown mottled sandy and micaceous clay, but apparently not glauconitic. The lower level is in stiff dark blue clay, with large solid calcareous doggers (? Kimeridge Clay). This brickyard is about 60 feet below the line of springs taken at the base of the Greensand, so that if the upper clay is Gault it is still fairly thick at this place.

It can be traced below the escarpment by Hillfield and Batcombe to Woolcombe, near Evershot Station, but is there much thinner. Sandy yellowish micaceous clay was seen by Mr. Whitaker at Woolcombe rail-crossing, and west of Melbury Bubb, but stiff bluish Oxford Clay comes in along the line of railway by the latter place. It is evident that the Gault is here thinning out, and it has not been observed at any point between Evershot and the western termination of the escarpment.

Upper Greensand.

The lower part of the Greensand is not well exposed anywhere between Shillingstone and Woolland, but in one or two places a passage can be traced from sandy micaceous clay into fine micaceous sand, and the latter passes up into greenish-grey sand without mica.

The highest part of the Greensand is well exposed in a sand-pit about half a mile south of Okeford Fitzpaine, and the section here is as follows:—

	Feet.
Soft glauconite marl (base of Chalk Marl) seen in one part	1
Dark glauconite sand with many fossils, containing in the upper part many hard compact calcareous concretions which enclose decomposed green-coated nodules and bits of brown phosphate - - - -	2
Dark greensand with irregular concretions of calcareous glauconitic sandstone -	7
Soft dark greensand with a few concretions, passing down into clean greenish-grey sand	20
	30

The special interest of this section lies in the fossils which occur in the greensand and the topmost calcareous concretions:

the fauna is clearly that of the Rye Hill sand near Warminster, and the bed occupies a similar position just below the glauconitic marl which forms the base of the Chalk. I found the following fossils here:—

Ammonites varians.	Pecten (Neithea) 4-costatus.
„ Mantelli.	Terebratella pectita.
„ sp.	Rhynchonella grasiana.
Exogyra conica.	Catopygus carinatus.
„ sp.	Holaster lævis.
Avicula gryphæoides.	Discoidea subucula.
Pecten asper.	Salenia petalifera.
„ Galliennei.	Micrabacia coronula.

In the lower beds the only fossils found were *Exogyra conica* and *Serpula concava.*

The beds seen in this pit dip at about 5° to the east towards a line of fault, and the whole outcrop of the Greensand is only about 500 feet wide; this on a level surface would bring in about 44 feet, but there is a fall of 30 feet from the top to the base, so that the total thickness is about 74 feet.

The outcrop of the Upper Greensand between Woolland and Evershot has not yet been re-surveyed, but Mr. Whitaker traversed the district in 1892, and reports that the slopes below the base of the chalk are generally very steep, and that the breadth of the tract really occupied by the outcrop of the sands is very narrow. As, however, many landslips have occurred, it is not easy to draw any line for the base of the Greensand, but it is certain that the line on the old map has been drawn too low down.

As far as Mr. Whitaker could judge, the total thickness of the Greensand between Woolland and Buckland Newton does not exceed 60 feet, and round the Dungeon Hill outlier north of Buckland Newton the thickness is still less. At the northern end of this outlier the vertical space occupied by Greensand was estimated by Mr. Whitaker at not more than 30 feet. At and near Buckland there is apparently 50 or 60 feet, and further west it increases to 100 feet, so that the diminution of thickness seems to be quite local.

The mass of the Greensand along the escarpment consists of soft sands in which there are few exposures, but at the very summit of the formation is a bed of hard, nodular and rather fine-grained glauconitic sandstone. This appears to set in at or just to the south of Stoke Wake, and can be followed by frequent exposures from this point along the escarpment to and beyond Evershot. The rock consists of quartz and glauconite grains cemented together by calcite into a very hard stone, which has a decided green colour from the abundance of glauconite. The quartz-grains are mostly small, with here and there a large grain, but the grains of glauconite are rather large and, from their dark green colour, are conspicuous.

From Melcombe Bingham westward its average thickness is about 6 feet, and from that place to Dogbury Hill the upper foot or 18 inches of the mass encloses many phosphatic nodules and phosphatic casts of fossils of a dark brown colour; some of these are rolled, others seem quite unworn.

The upper surface of the glauconitic stone is waterworn and uneven; much green matter has been washed into its joints and cracks, and often surrounds the phosphate nodules.

The fauna of this phosphatic bed is a remarkable one, for it contains many Cephalopoda, some of them being species which are very rare in England, and only known from the zone of *Am. rostratus*, while others are such as occur in the highest bed of the Warminster Greensand or zone of *Pecten asper*.[1] Most of the former are phosphatic casts, and may have been derived from some older deposit, though no deposit containing such nodules and fossils is yet known in the south-west of England. *Ammonites Studeri* for instance is only known from the Upper Gault of Folkestone and from the Cambridge Greensand (derived); *Ammonites dispar* is a species which is not known to occur elsewhere in England, though *Am. rhamnonotus* of the Cambridge Greensand is closely allied to it.

The glauconitic sandstone is exposed in a quarry north-east of the church at Melcombe Bingham, where the phosphate nodules and fragments are distributed through nearly two feet of its thickness, and the rock is a sort of phosphatic conglomerate.

It is also seen by a spring-head east of Melcombe Horsey, and in the road north of that place; in the road-cutting at Dorsetshire Gap, and by the roadways on each side of the valley south of Armswell Farm, but the phosphate bed here is not much over a foot thick.

One of the best sections is at Bookham Farm, in the farmyard, where both top and base are exposed, thus:—

	Feet.
Whitish Chalk, passing down into chalk with green grains, and a few phosphatic nodules - -	5
Hard nodular glauconitic sandstone with many phosphate nodules and fossils in the top six inches, very hard and compact below, about - -	6
Soft sand, with lumps of hard calcareous stone, seen for	1

Near the top of the sandstone I found *Ammonites Studeri Modiola sp.* and *Parkeria sphærica* (all phosphatised) with *Exogyra digitata*; *Plicatula inflata*,; *Pectunculus sublævis*; *Lima semiornata*, *Rhynchonella dimidiata* and *Actæon sp.* Mr. Rhodes afterwards collected from this and the other places above mentioned, and a full list of the fossils from this bed will be found on p. 168.

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[1] An account of this bed and its contents was given by me in the Proceedings of the Dorset Nat. Hist. and Ant. Field Club, vol. xvii., p. 96. (1896).

On Dogbury Hill, north of Minterne, there is a quarry in this sandstone, the highest six inches enclosing some green nodules and a few phosphatic fossils like those at Bookham, this being the most westerly place where such fossils were noticed. Those found here were *Ammonites Studeri*, *Turrilites Bergeri*, *Actæonella sp.*, *Natica sp.* The stone also yielded *Holaster lævis*, *Catopygus carinatus*, *Rhynchonella latissima*, *Pecten asper*, and other fossils with calcareous shells.

An exposure above the road west of Dogbury Gate shows the whole thickness of the top sandstone which passes down into greenish sand with concretions of hard calcareous stone. Below this is sand full of broken shells, about three feet, and still lower about three feet of irregular lumpy calcareous sandstone. Half a mile further west, and on the north side of the road is a sand-pit showing the lower lumpy sandstone, underlain by soft greenish grey sand (five feet seen).

This lower sandstone contains quite a different set of fossils from the upper bed, fossils which prove it to belong to the zone of *Am. rostratus*. Most of them are casts, but some are external moulds, and the following can be identified:—

Ammonites rostratus (large).	Exogyra conica.
Trigonia aliformis.	Cyprina cuneata.
„ Meyeri ?.	,, rostrata ?
Cardium hillanum.	Pecten (Neithea) quadricostatus.
Lucina sp.	Cucullæa glabra ?

Where the road turns north to Hermitage is another sandpit, about 10 feet deep, showing grey bedded sand, with a few small calcareous concretions and a layer of *Exogyra conica* and fragments of *Pectens*.

A still lower horizon is exposed in a sandpit on the north-western slope of Dogbury Hill, which shows about 12 feet of fine yellowish-green sand, composed mainly of small even-sized grains of quartz and glauconite, but containing some flakes of white mica. About the middle is a band of loamy sand, full of *Exogyra conica* and broken *Pecten quadricostata*. The floor of this pit is about 70 feet below the base of the Chalk, and the spring-heads are about 50 feet lower, so that the Greensand seems to be 120 feet thick at this place, unless some of it has slipped down the slope.

The upper stony part of the Greensand is exposed in several pits near Minterne and Cerne, the top sandstone being quarried and used as a building-stone. Two small pits just north of Cerne Abbas give the following combined succession:—

		Feet.
Zone of *P. asper*	Hard nodular calcareous glauconitic sandstone with many *Pecten asper* and some other fossils	4
	Soft greensand with many broken shells and perfect *Exogyra conica*, *Rhynchonella grasiana*, *Discoidea subucula*, and *Echinobrissus lacunosus* - -	3
Zone of *A. rostratus.*	Similar sand agglutinated by calcite into a rubbly stone, but few fossils - -	3
	Soft greensand with scattered calcareous concretions	4

The following is a list of the fossils which have been found in this phosphate-bed at the top of the Upper Greensand at the localities above mentioned. The first column shows those collected by the Geological Survey, the second column is a list of the collection in Dorset County Museum at Dorchester, for the naming of which I am chiefly responsible, some specimens, however being submitted to Mr. Sharman and Dr. Hinde.

The letter "p" indicates that the fossil is preserved in brown phosphate, the letter "s" that it occurs either as a shell or as a cast in the sandstone matrix.

	Geol. Survey.	Dorchester.
Sponges.		
Siphonia tulipa, *Zitt.*		p
(? Lithistid Sponge) -	–	p
(? Hexactinellid Sponge	–	p
? Hydrozoa.		
Parkeria (two species)	–	x
Actinozoa.		
Micrabacia coronula, *Goldf.*	–	s
Onchotrochus Carteri, *Dunc.*	–	s
Echinodermata.		
Cardiaster fossarius, *Benett.*	–	s (one)
Catopygus columbarius, *Lam.*	p and s	p and s
Discoidea subucula, *Klein.* -	p and s	p and s
Echinobrissus lacunosus, *Goldf.*	s	s
Echinoconus castanea, *Brong.*	–	s
Goniophorus lunulatus, *Ag.*	–	s
Hemiaster minimus, *Ag.* -	s	–
Holaster lævis, *Deluc.* (carinatus)	s	p and s
Peltastes clathratus, *Ag.* -	s	s
Pseudodiadema Benettiæ, *Forbes* -	–	p
,, variolare, *Ag.* (var Roissyi)	–	s
Pygurus lampas, *De la Beche*	s	–
Salenia petalifera, *Desm.*	–	s
Annelida.		
Ditrupa difformis, *Lam.*	–	s
Serpula plexus, *Sow.*	s	s
,, antiquata, *Sow.*	s	s
,, (Vermicularia) concava, *Sow.*	s	s
Crustacea.		
(Claw of crustacean)	p	p
Polyzoa.		
Desmepora semicylindrica ?, *Röm.*	–	s
Onychosella sp. - - - -	–	s
Pustulipora pustulosa, *Blainv.*	–	s
Radiopora ornata, *d'Orb.* (Cellulipora)	–	s
Reptomulticlausa papularia, *d'Orb.* - -	–	s

———	Geol. Survey.	Dorchester.
Brachiopoda.		
Rhynchonella dimidiata, *Sow.*	s	s
„ „ var. convexa, *Sow.*	s	s
„ grasiana, *d'Orb.*	s	s
„ mantelliana, *Sow.*	s	s
„ Schlœnbachi, *Dav.*	–	s
„ Wiesti ?, *Dav.*	–	s
Terebratula biplicata, *Sow.* -	p	p and s
„ arcuata, *Roem.* -	–	s
„ ovata, *Sow.* -	s	s
„ semiglobosa, *Sow.* -	s	s
„ squamosa, *Mant.*	s	s
Terebratella Beaumonti, *d'Arch.*	s	s
„ Menardi, *d'Orb.*	–	s
„ pectita (one, doubtful) -	–	s
Terebrirostra lyra, *Sow.* -	–	s
Terebratulina striata, *Wahl.*	–	s
Lamellibranchiata.		
Arca Galliennei ?, *d'Orb.*	–	p
„ pholadiformis, *d'Orb*	–	p
„ seriata ?, *d'Orb.* - - -	–	p
„ (Cucullæa) glabra, *Park* (=fibrosa, *Sow.*)	p	p
„ „ mailleana, *d'Orb.* - -	p	p
Cardium gentianum *Sow.*	p	–
„ alutaceum ?, *Goldf.*, or new sp.	–	s
Cardita tenuicosta, *Sow.*, or dubia, *d'Orb.*	p and s	p
„ cottaldina, *d'Orb.*	–	p
Corbula, sp. - -	–	p
Cucullœa (see Arca)	p	p
Cyprina sp.	p	p
Exogyra conica, *Sow.*	s	s
„ columba, *Sow.*	s	s
„ digitata, *Sow.*	–	–
Gervillia sp.	p and s	–
Isocardia sp. -	p	–
Lima ornata, *d'Orb.* - -	s	–
„ semiornata, *d'Orb.* - -	–	p
„ semisulcata, *Sow.* -	s	s
Modiola, (near to æqualis, *Sow.*)	p	–
Mactra sp.	–	p
Mytilus sp. (small) -	–	p
Ostrea canaliculata, *Sow.* -	–	s
„ frons, *Park.* (=carinata, *Sow.*)	s	s
„ vesiculosa, *Sow.*	–	s
„ vesicularis, *Sow.*	p	–
Pecten asper, *Sow.* -	s	s
„ Galliennei, *d'Orb.* -	s	s
„ hispidus, *Goldf.*	s	–
„ orbicularis, *Sow.*	s	s
„ (Neithea) æquicostatus, *d'Orb.*	–	s
„ „ cometa, *d'Orb.*	p and s	s
„ „ quadricostatus, *Sow.*	s	s
„ „ quinquecostatus, *Sow.*	s	s
Pectunculus sublævis, *Sow.*	p	p

———	Geol. Survey.	Dorchester.
Lamellibranchiata—cont.		
Pleuromya	s	–
Plicatula inflata, *Sow.*	s	–
,, pectinoides, *Sow.*	s	–
Spondylus striatus, *Sow.*	s	s
,, like dutempleanus, *d'Orb.*	s	–
Tellina striatula, *Sow.*	–	p
,, sp.	–	p
Trigonia crenulifera, *Lyc.*	–	p
,, spinosa, *Park.*	–	s
,, vicaryana, *Lyc.*	–	p
Unicardium	p	p
Venus sp.	p	–
Gasteropoda.		
Avellana incrassata, *Mant.*	p and s	p
Natica Genti ?, *Sow.*	p	–
Pleurotomaria Gibbsi (?), *Sow.*	–	p
,, (species with shell)	–	p
,, (several species, casts)	p	p
Trochus sp.	p and s	–
Fusus sp.	p	p
Solarium Binghami, *Seeley*	–	s
,, sp.	p	–
? (Genus like Helix)	–	p
Cephalopoda.		
Ammonites dispar, *d'Orb.*	p	p and s
,, Coupei, *Brong.* (rare)	p	–
,, falcatus, *Mant.*	p and s	p and s
,, navicularis, *Mant.*	p	–
,, octosulcatus ?, *Sharpe*	p	–
,, raulinianus, *d'Orb.*	–	p
,, renauxianus, *Sharpe* (non *d'Orb.*)	p	–
rostratus, *Sow.* (rare)	p	p
,, Salteri, *Sharpe*	p	–
,, splendens (?), *Sow.*	p	p
,, Studeri, *P. & C.*	p	p
,, varians, *Sow.* (rare)	p	p
,, vraconnensis ?, *P. & C.*	–	p
Ancyloceras or Hamites	p	–
Anisoceras armatus, *Sow.*	p	p
Baculites baculoides, *Mant.*	p	p
Belemnites sp.	s	–
Hamites rotundus ?, *Sow.*	–	p
Nautilus sp.	p	p
Turrilites Bergeri, *Brong.*	p	p
,, costatus ?, *Lam.*	p	–
,, puzosianus, *d'Orb.*	p	p
Helicoceras ?	p	–
Vertebrata.		
Lamna appendiculata, *Ag.* (tooth)	x	–
Ptychodus decurrens, *Ag.* (tooth)	x	–

CHAPTER XII.

UPPER GREENSAND (SELBORNIAN) IN WEST DORSET, SOMERSET AND DEVON.

West Dorset.

Upper Greensand.

Under this heading will be included the upper part of the Valley of the Frome from Evershot to Maiden Newton, and the outcrops west of this line as far as Beaminster and Cheddington where the main outcrop ends; also the escarpment which extends from near Maiden Newton, by Eggardon Hill, and Askerswell, to Little Bredy, north of Abbotsbury.

No representative of the Lower Gault has been found in this part of Dorset, but as the base of the formation is nowhere exposed, we cannot be sure that it has completely thinned out, though it probably does so to the north of Beaminster.

The Upper Greensand has a thickness of about 100 feet near Beaminster and Maiden Newton, but increases southwards to 160 feet; the greater part of this thickness belonging to the zone of *Ammonites rostratus*.

The lowest visible beds consist of fine argillaceous and micaceous sand, which, in the more western part of the area contain large lenticular masses of grey compact calcareous sandstone exactly like those which are called "cowstones" near Lyme Regis. These micaceous sands pass up into soft grey and yellowish sands, and these into greenish sand surmounted by 2 or 3 feet of rubbly glauconitic sandstone like that previously described near Cerne and Evershot. This seems to be the top of the zone of *Ammonites rostratus*.

Above this stony bed there is greensand passing up into coarser sand-rock, which in turn passes up into a hard calcareous grit. This grit consists chiefly of large rounded quartz grains set in a matrix of finer quartz sand, and cemented into a hard rock of crystalline calcite. There are some glauconite grains scattered through it, but so few that the general tint is yellowish-grey, weathering to a yellowish-brown. This calcareous grit is visible in many places, and often forms a visible feature, sometimes projecting through the soil and forming a ledge or floor where it is crossed by the roadways. It is the equivalent of the glauconitic sandstone of North Dorset, which can be traced to the south of Evershot passing into this coarser and less glauconitic rock.

In the western part of the district beds of soft siliceous earth containing lumps and layers of chert come in below this calcareous grit, and are evidently the beginning of the Chert-beds which form such a conspicuous part of the formation in Devonshire.

The exposures in the Valley of the Frome near Maiden Newton

may first be mentioned. The lowest beds are visible in the railway-cutting south of Evershot Station, and in the ditches by the side of the railway west of Chalmington; they consist of fine soft argillaceous and micaceous sand, grey, wet and semi-plastic.

The beds which form the top of the zone of *Ammonites rostratus* are exposed in the steep bank by the fruit-garden south of Chalmington House, this showing about 6 feet of greenish grey sand passing up into rubbly glauconitic sandstone full of *Exogyra conica* and broken *Pecten (Neithea) quadricostatus.*

A better exposure occurs in a sand pit at Higher Wraxall, south-west of Rampisham, which shows the same glauconitic sandstone 2 or 3 feet thick, and containing *Ex. conica* and a large *Ammonites rostratus.* Beneath are about 9 feet of soft greenish-buff sand, consisting of quartz and glauconite in very even sized grains.

The hard calcareous grit which forms the summit of the Greensand has been quarried at many places—namely, at Higher Wraxall, north of Chilfrome, east of Cattistock, west of Maiden Newton, near Toller Fratrum, on the road from Tollerford to Wynford, and on both sides of the valley beyond Wynford.

One of the best sections is in a quarry near Maiden Newton, on the road to Chilfrome, the beds seen here being:—

	Feet.
Clayey soil piped into glauconitic chalk, with a layer of phosphatic nodules and fossils at the base - -	2 to 3
Coarse calcareous grit, very hard in the upper part, passing down into a coarse sandstone with hard nodules of fine-grained calcareous sandstone - about	6
Loose and rather coarse sand-rock, weathering into sand, used for garden gravel - -	4
About	12

The beds are nearly horizontal. The upper surface of the calcareous grit is decomposed, waterworn, and stained with green matter which penetrates the cracks for six or seven inches. The commonest fossils in the grit are *Catopygus columbarius* and *Holaster lævis*, but the following is a list of the species which I obtained from it:—

Pleurotomaria sp. (large).
Exogyra conica.
Lima semisulcata.
„ ornata.
Modiola Cottæ.
Ostrea (large flat species).
Pecten asper.
„ orbicularis.
„ (Neithea) æquicostatus. ?
„ „ quadricostatus.
Pectunculus sublævis.
Plicatula inflata.
Terebratula ovata.
Terebrirostra lyra.
Caratomus rostratus.
Cardiaster fossarius.
Catopygus columbarius.
Epiaster Lorioli.
Discoidea subucula.
Holaster lævis.
Pseudodiadema Benettiæ.
Rhynchonella dimidiata var. Schlœnbachi.
Cottaldia Benettiæ.

At Cattistock a curious modification of the grit is seen, patches of very fine-grained stone occurring not only near the base, but

up to within a foot or so of the top not as separate nodules, but simply as portions of the rock which are free from large grains of quartz. They merge into the surrounding parts, which are full of such large grains, and it is not easy to understand why these large grains should not have been equally distributed through the mass.

Eggardon Hill, four miles south-west of Maiden Newton, is another place where the succession of the beds which form the Greensand can be conveniently studied. The exposures near the summit were thus described by Mr. Whitaker in 1870[1]:—"On Eggardon Hill, N.E. of Bridport, the Upper Greensand forms rocky ledges at the base of the Chalk, the highest being of a more or less calcareous grit of irregularly weathered (? calcareous) sandstone with dark grains and full of fossils. Between these is green grey sand, full of stony nodules in the higher part, and indeed passing up into the stone above. The grey rocks clad with lichen, small ferns, and ivy are very pretty."

South of Eggardon Hill the slope is formed by a succession of landslips, but near Spyway the Chert-beds, consisting of fine light-grey sands with nodules of chert, appear below the calcareous grit, and have been quarried to the north-east of Askerswell.

The calcareous grit, with *Catopygus columbarius, Rhynchonella Schlœnbachi, Terebratella pectita, Lima semisulcata,* and *Pecten orbicularis,* is exposed by the side of the Bridport road at the west end of Chilcombe Hill; and the base of the Gault, as far as can be determined, among the landslips, lies about 160 feet below. This estimate receives confirmation in the outlying mass of Shipton Hill, where the base of the Gault occurs at the 400 feet contour, while the hill reaches a height of 559 feet, without including any part of the calcareous grit. Allowing 8 feet for the thickness of that rock we may infer that the combined Gault and Upper Greensand are not less than 167 feet thick.

From Chilcombe Hill the outcrop trends south-eastward by Litton Cheney, Long Bredy, and Little Bredy, till it is cut off the great fault near Abbotsbury.

The following note is taken from Mr. Strahan's memoir, "Long Bredy Hut Lane, which leads up to the Downs between Downfield Farm and Long Barrow, passes three sandpits; in these the strata dip northwards at 35 and present the following details"[2]:—

	Feet.
Calcareous grit, top not seen - - -	1
Soft streaky glauconitic sand with chert	10
Gap between two of the pits.	
Hard nodular green rock with *Exogyra conica*	8
Greensand with nodular rock -	10
Soft brown sand with great doggers (seen in the pit on the east side of the road) -	30
	59

[1] "On the Chalk of the Southern Part of Dorset and Devon."—*Quart. Journ. Geol. Soc.*, vol. xxvii., p. 96.
[2] Geology of the Isle of Purbeck and Weymouth, p. 160.

Returning to the northern part of the district and following the outcrop from Maiden Newton towards Beaminster, we find that near Hooke and Toller Whelme (or Pinny's Toller) two changes of much interest set in. Several small quarries at these places expose the junction of the Chalk and the Greensand, and though at a hasty glance it seems similar to that near Maiden Newton, a closer examination shows that the topmost foot of the calcareous grit has a different appearance. It is much more calcareous, having a whitish calcareous matrix enclosing numerous quartz grains, both large and small; it contains many fossils, *Ammonites varians* and *Am. Mantelli* being common, some of them broken and worn before embedment, but others complete casts filled with the rock-matrix, and not phosphatised. There are also lumps of a thick irregular calcareous organism, which are very rotten, and split up into curved layers, and seem to be a kind of sponge. These are so abundant in places as to give quite a character to the rock; they are so decomposed that Dr. Hinde, to whom specimens were sent, could find no structure in them, though he found stems of *Nematinion* associated with them.

The rock is piped and stained with greenish matter, and contains lumps of a greenish sandstone; its upper surface is uneven and worn into rounded hollows and bosses which are coated with a thin layer of brownish phosphate. On this rests the usual basement nodule-bed of the Chalk.

The upper foot of rock above described is not in any way marked off from the sandstone below, but passes down from a sandy limestone into a coarse quartz-grit which at a depth of three or four feet down has a greenish tinge, the base not being seen. This grit contains *Pecten asper* and *Catopygus carinatus* as near Maiden Newton, and the Ammonites are confined to the uppermost 12 inches.

The appearances suggest that there were originally passage-beds between Chalk and Greensand here just as there are at Warminster, namely, a calcareous sand with a fauna like that of the Rye Hill sand, succeeded probably by a Chloritic Marl with phosphatic nodules; that these passage-beds were broken up and destroyed with the exception of the very bottom layer which had become calcified and consolidated into one mass with the underlying sandstone.

This fossiliferous layer has been found again near Beaminster, but does not seem to occur at Cheddington, so that it is of small extent.

The following fossils were obtained by me from the localities above mentioned, and I am responsible for the determination of the species:

Ammonites Mantelli.
„ varians.
Nautilus sp.
Scaphites æqualis.
Turrilites tuberculatus.
Acmæa.
Pleurotomaria (2 species).
Trochus (cast).

Corbis sp.
Exogyra conica.
Ostrea vesiculosa.

Inoceramus sp.
Nucula obesa.
Pecten asper.
„ puzosianus.
Plicatula inflata.
Pectunculus sublævis ?.
Trigonia vicaryana.

Catopygus columbarius.
Cottaldia Benettiæ.
Discoidea subuculus.
Holaster subglobosus var. altus.
„ lævis.

The other change mentioned on p. is the recurrence of the Chert-beds, which are absent over such a wide space in North Dorset. We are satisfied, too, that their non-occurrence in that area is a real absence of the beds, and not merely of the chert nodules, as in some other places.

Traces of the spicular sands and cherts were noticed north-east of Beaminster, and a good section is exposed in a quarry on the west side of Stinsford Lane north of Beaminster.

The beds seen here in 1895 were as follows:—

	Feet.
Whitish mealy siliceous marl, with a thick layer of chert at the top, large chert nodules, scattered through middle part, and whitish calcareo-siliceous stone at base	7
Thin layer of loose sandstone pebbles coated with green matter.	
Hard greenish glauconitic calcareous sandstone, thickness irregular from 1 to	2
Dark green sand with calcareous lumps -	2
Greenish sand with calcareous lumps and rusty stains passing down into soft green sand -	6

Another pit on the opposite side of the road is dug still deeper into the same greensand. Higher up the roadway the Chert-beds are seen again, succeeded by the calcareous grit which forms the summit of the Greensand.

The above section shows that the Chert-beds come in between this calcareous grit and the lower bed of green calcareous sandstone which was seen at Eggardon and Chalmington; the lower sandstone being apparently the top of the zone of *Ammonites rostratus*. In the Stinsford Lane quarry the layer of sandstone pebbles seems to indicate a slight erosion and current action, and very small bits of green-coated stone are included in the overlying bed.

No fossils were found in the Chert-beds, but the following occur in the green stone and sand below:—

Neithea quadricostata (common).
Pecten orbicularis.
Exogyra conica (abundant).
Discoidea subuculus.

It is interesting to note that although no trace of Gault clay has been observed near Beaminster, yet that dark grey micaceous sand, containing large burrs or doggers of hard and compact grey sandstone, like the Cowstones of the coast sections near Charmouth, has been seen at two localities. Near Marsh Farm, 1½ miles east of Beaminster, there are slipped masses of these lowest sands, and the sandstone burrs lie in the watercourse which drain into the valley below. Again a mile and a half north-west of Beaminster, at the southern entrance to the

tunnel on the main road, these sands and burr stones may be seen in place, the stones here resembling the upper layers of the Cowstones at Black Ven. The exposure appears to be about 20 feet above the base of the Greensand, and the total thickness of the formation here may be a little over 100 feet.

A higher part of these micaceous sands is exposed in sand pits on Crook Hill, north of Cheddington. The sand here is fine, soft, buff coloured and micaceous, and in the pit at the west end of the hill I found lenticular patches of brown ferruginous sand crowded with a small *Avicula*, resembling *pectinata*, Sow. In the soil at the top of the pit on the south slope are valves of *Exogyra conica* silicified. There is another sand pit at Hilliards Corner nearer Cheddington, and in this sand casts of *Lucina* and other shells are discernible.

Borders of Somerset and Devon.—Crewkerne and Chard.

Upper Greensand.

Beyond the north-western termination of the main escarpment of the Upper Greensand in Dorset there are several outlying tracts varying greatly in size, but most of them capped by outliers of Chalk, so that they include the full thickness of the Greensand. These lead on to the larger tract of Cretaceous sands which extends from the neighbourhood of Chard to the Blackdown Hills; in the eastern part of this tract around Membury, Chard, and Combe St. Nicholas, there are again outliers of Chalk, beneath which the highest beds of the Greensand are preserved.

South of Crewkerne the thickness of the Greensand is not much over 100 feet, and the succession of beds is the same as near Beaminster, but as they are followed westward to Chard several parts of the formation increase in thickness, and the total amounts to about 180 feet. Thus the Chert-beds, which near Crewkerne are only five to six feet thick, thicken to 25 and 30 feet near Chard; and the soft yellowish sands which form the central part of the series and are commonly known by the name of "Foxmould," reach nearly twice the thickness they have in West Dorset.

Nowhere in this area have the basement-beds been observed, but it is supposed that they correspond with the grey sands and "Cowstones" of the coast section. The beds referable to the zone of *Ammonites rostratus* must be about 140 feet thick, and they terminate with a speckled glauconitic sandstone like that described in West Dorset. The zone of *Cardiaster fossarius*, including the Chert-beds and the calcareous grit, varies from 16 to 40 feet in thickness.

Sand-pits and road-cuttings in the outliers south and south-

west of Crewkerne show that the succession there existing is as follows:—

		Feet.
5 *b*.	Hard nodular quartziferous limestone, with green stains and coatings, passing down into hard nodular calcareous grit, and finally into coarse glauconitic sand with hard calcareous nodules - - -	8
5 *a*.	Coarse sand, chiefly quartz, but with some glauconitic grains, enclosing some hard white calcareous concretions	2 to 2½
4 *b*.	Greyish-white fine-grained coherent sand, with white siliceous stone and irregular layers of light brown flinty chert - - - - - - - -	5 to 8
4 *a*.	Dark green glauconitic sand, with large lumps of greenish calcareous sandstone, and in some places smaller green-coated nodules derived from the bed below - - -	1 to 1½
3.	Rubbly whitish calcareous sandstone, with green grains passing down into nodular calcareous sandstone and glauconitic sand with calcareous lumps - -	10 to 12
2.	Greenish-grey sand, with lenticular masses of sand consolidated by chalcedonic silica - - - -	6
1.	Soft yellowish-green sands, passing down into soft loamy micaceous yellow sand, about - - - - -	70
	Over	100

Beds 2, 3 and 4 are exposed in the lane ascending Shave Hill, south of Crewkerne, and in a quarry at the corner of the lane to Henley. The glauconitic sandstone No. 3 is evidently the continuation of the lower sandstone of Eggardon Hill and Beaminster; it is full of *Exogyra conica*, and also yields *Pecten* (*Neithea*) *quadricostatus*, *Lima semisulcata*, *Rhynchonella dimidiata*, *Catopygus columbarius*, *Echinobrissus lacunosus* and spines of *Cidaris*. The stone here is in large irregular masses, which hardly form a continuous bed. Another good exposure of it is at the corner of the cross roads at Wayford, 2½ miles south-west of Crewkerne; here the rocky bed is overlain by greensand full of derived green-coated nodules, and among these are *Exogyra conica*, *Ex. columba*, *Pecten sp.* and *Rhynchonella dimidiata*. The Chert-beds come on above, and I regard this rubbly greensand as the base of the *Cardiaster fossarius* zone.

The most complete section however is in the road-cutting west of Warren Hill, 2¼ miles west of Crewkerne, this showing the whole from the junction with the Chalk down to the top of No. 1.

The nodular calcareous grit at the top is clearly a continuation of that in West Dorset, but it has a more nodular character owing to the fact that the fine sand is more separated into patches, which are fairly sharply defined from the coarser portions and in the lower part form definite nodular lumps. Fossils are less common in it than in Dorset.

The Chert-beds are here only 5 feet thick, but in a pit on Chillington Down, further west, 7 feet are exposed without reaching the base, and in a pit at Higher Chillington there are large reddish brown cherts in a layer of buff sand above the first 2 feet of coarse sand. Here too this coarse sand contains large *Pecten* (*Neithea*) *quadricostatus*.

Further west, near Chaffcombe, the calcareous grit becomes less quartziferous, and passes into a more calcareous stone, which is largely composed of fragments of comminuted shell, while the coarse sand below is replaced by white shell-sand. These beds are exposed in a quarry by Knapp Cottages, half a mile east of Chaffcombe, the section being as follows:

	Feet.
Soil and rubble of Chloritic marl - - - - - -	2
Hard calcareous grit with small *Rhynchonellæ*, and fragments of Crustacea (claws, &c.) - - -	$6\frac{1}{2}$
Soft white shell sand and sandstone - - -	3
Chert-beds, fine siliceo-calcareous sand with lenticular lumps of flinty chert - - -	10
	$21\frac{1}{2}$

The road-cutting through Hazlewood Hill, north-west of Winsham, shows 12 or 13 feet of chert-beds, underlain by 3 feet of nodular glauconitic sandstone with the usual fossils, and 8 feet of greensand with calcareous nodules.

At Snowdon Hill, west of Chard, there are large quarries where the chert-beds are quarried, and the Chalk above the Chloritic marl is burnt for lime, so that a fine section is exposed. The calcareous grit is here between 8 and 9 feet thick, very hard and quartzose throughout. The chert-beds consist of grey glauconitic sandstone cemented by calcite, with lenticular seams of chert, and nearly 30 feet of them are exposed. Further north are old quarries and caves whence the sandstone has formerly been dug for building-stone. The beds dip at about 5° to the west, and are broken by two parallel faults running nearly north and south, and about 30 feet apart, the block between them being raised five or six feet (*See* Fig. 60.)

There are large overgrown quarries on Storridge Hill east of Chardstock, and a small one still open on the Chard side of the boundary-hedge shows the calcareous grit dipping eastward at about 12°, passing down into a less calcareous sandstone, the whole about 8 feet thick and full of the claws and broken remains of crabs in the top 2 or 3 feet. Beneath are 5 feet of the Chert-beds.

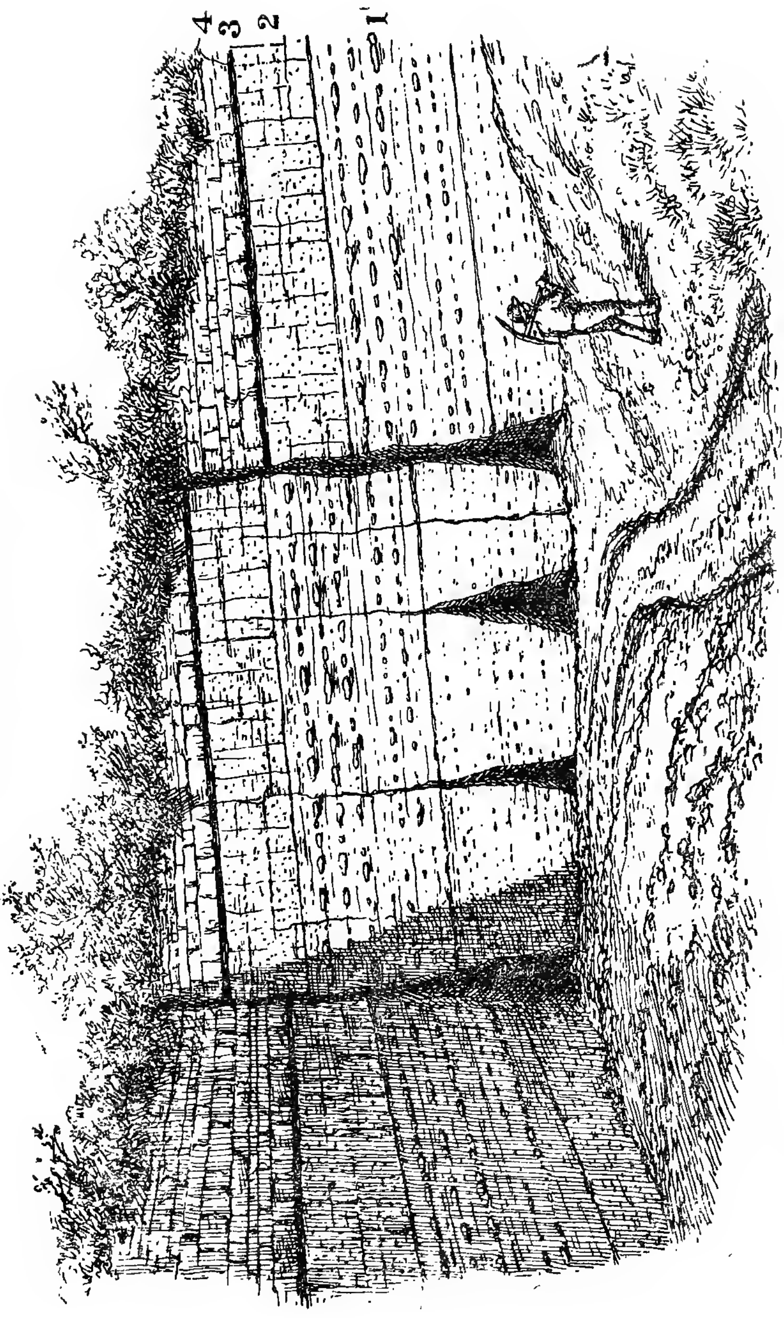
At the south end of Storridge Hill the lower part of the chert-beds with the underlying glauconitic sandstones are exposed, thus:—

	Feet.
Fine greyish sand with layers of chert - - - - - -	5
Hard nodular glauconitic sandstone with calcareous cement, containing a few nodules of chert at the base - - -	$4\frac{1}{2}$
Coarse greenish glauconitic sand with scattered lumps of calcareous sandstone - - - - - - - - -	$3\frac{1}{2}$

There is no greensand here above the sandstone, but its upper surface is decomposed and loose with green-coated nodules of sandstone and broken shells.

From the above account it will be seen that I cannot entirely

FIG. 60.—*View of Snowdown Quarry near Chard.*[1]



4. Lower Chalk.
3. Chloritic Marl.
2. Calcareous Sandstone } Upper Greensand.
1. Chert-beds } Upper Greensand.

[1] *See* also H. B. Woodward, Geol. England and Wales, Ed. 2, p. 392.

confirm the succession given by Mr. Davidson in 1852 on the authority of Mr. J. Wiest.[1] His Scaphites Bed (No. III.) is clearly the hard nodular base of the chloritic marl, and below this he distinguishes three other beds as follows:—

"IV. *Green Bed*, near Chardstock, distinctly separated from III., forms a hard compact mass of rocks, with abundant siliceous and chloritic grains, from six inches to three feet in thickness, and containing the greatest variety of fine fossils. *Nucleolites Morrisii*, *N. lacunosus*, *Terebrirostra lyra*.

"V. *Crustacean Stratum*, less cemented than IV., with siliceous grains predominant, one to three feet in thickness. It contains a few *Terebratulæ* and *Pectens*, but chiefly remains of crabs.

"VI. *Nautilus lævigatus layer*, a loose sand nearly one foot in thickness, containing but few fossils.

The total maximum thickness of these three beds being only 7 feet, it is obvious they must be portions of the bed I have described as "calcareous grit." This certainly contains a greater number of fossils in the upper part than the lower, but it is in this upper part that Crustacean remains are also abundant, particularly east of Chardstock, where the top part is crowded with them. It is strange therefore that Mr. Wiest should describe them as occurring in a stratum from ½ foot to 3 feet below the top. He seems, however, to have collected carefully from the deposit, and the Brachiopods mentioned by Mr. Davidson as occurring in his Beds IV. and V. are:—

Terebratula semiglobosa ?	Rhynchonella compressa (= dimidiata, var. convexa).
" ovata.	" depressa (= Schlœnbachi).
Kingena lima.	" nuciformis (doubtful).
Terebratella pectita.	" grasiana.
Terebrirostra lyra.	
Rhynchonella latissima (dimidiata).	

All these, except perhaps the first, are Warminster Greensand species. Mr. Wiest mentions *Nucleolites* [*Echinobrissus*] *Morrisii* and *N. lacunosus* as occurring in Bed IV., while Dr. Wright quotes the latter from Chardstock Chloritic Marl; but as Wright also says he obtained his best specimens of *Catopygus carinatus* from "the Chloritic Marl near Chard," I think he must have regarded the calcareous grit as part of the Chloritic Marl, for that fossil is certainly not common in the latter, and the best specimens I have seen came from the calcareous grit of Maiden Newton.

As Mr. Wiest says, the plane of division between the calcareous sandstone and the Scaphites bed, or noduliferous base of the Chalk Marl, is distinct, and fallen blocks in the quarry at Chard often split along this plane showing a surface crowded with broken shells, especially of *Trigoniæ*; the hollows and cracks are filled with green matter, but the shells are confined to a few inches at the top of the sandstone, and this I suppose to be Mr. Wiest's "green bed."

It is a curious fact that *Pecten asper* has not been found in the calcareous sandstone of this district, but is common in the overlying nodule-bed at the base of the Chalk.

The soft sands which form the lower portion of the Greensand are not often exposed near Chard, but a sandpit on Foxdon Hill

[1] "Cretaceous Brachiopoda," Pal. Soc., 1852, Part ii., p. 114.

near Wadeford shows about 30 feet of them. The upper seven or eight feet are green sand, with lenticular nodules of very impure sandy chert; the lower part consists of clean yellowish-green sand, without fossils or cherts. This appears to be about 100 feet above the base of the Greensand.

Sand which appears to be about 30 or 40 feet above the base is dug by the road to Crewkerne, about a mile east of Chard, and consists chiefly of small even-sized quartz-grains, with enough disseminated glauconite to give it a greenish tint, and a smaller quantity of mica.

There is also a small outlier of sand at a place called Hornsbury, a mile and a half north-east of Chard, the highest part of which cannot be more than 20 feet above the base, and yet the sand here is not markedly micaceous; it is much weathered and oxidised to a yellow colour, and is capped by a patch of gravel. Dr. Spicer, of Chard, possesses some lumps of shelly sand which were said to have come from Hornsbury Hill pits. The fossils are silicified and resemble Blackdown specimens. Among them are *Cardium hillanum, Trigonia dædalea, Trigonia scabricola?, Cytherea* sp., *Cytherea caperata?* and *Avellana incrassata.* If they really came from this locality they are interesting as connecting the basal sands of the Chard district with those of the pits at the western termination of the Blackdown Hills.

Putting together all the exposures of Upper Greensand seen near Chard, we have the following succession for the Selbornian of this district:—

	Feet.
Hard nodular calcareous grit passing down into softer sandstone with calcareous lumps, and sometimes largely composed of shell sand -	8 to 9
Soft greyish fine-grained sand, sometimes cemented into a sandstone by calcite, enclosing lenticular layers and nodules of black chert - - -	25 to 30
Hard calciferous glauconitic sandstone, passing down into coarse greenish glauconitic sand, with lumps of calcareous grit - - - - -	8 to 10
Green sand with broken shells and lenticular lumps of impure sandy chert	10 to 12
Soft fine greenish-yellow sand, consisting of small grains of quartz and glauconite. Similar yellowish sand becoming slightly micaceous in the lower part; base not seen -	120 or more
About - - -	180

CHAPTER XIII.

GAULT AND UPPER GREENSAND (SELBORNIAN) IN SOUTH DORSET AND DEVON.

Coast Sections from Golden Cap to Axmouth.

The sections now to be described lie partly in Dorset and partly in Devon. The distance between Shipton Hill east of Bridport and Golden Cap to the west of that town is about six miles, and in this space a certain amount of change seems to have taken place in the composition and thickness of the formation.

Along the main outcrop in South and West Dorset the Gault has not been seen, but the occurrence of clay in the place of the (Lower) Gault along the coast near Charmouth and Lyme Regis makes it probable that it really continues through Dorset. Every part of the formation, however, seems to be thicker in these coast sections; the Gault and the overlying soft sands together seem to be at least 170 feet thick near Lyme, and there is a thick capping of chert gravel on Timber Hill above, which is accounted for west of Lyme by about 60 feet of sandstones with layers and nodules of chert, so that the total thickness near that place may be from 220 to 230 feet, as compared with only 167 feet near Bridport (*see* p. 173).

The overstep of the Cretaceous beds over the members of the Jurassic series is very conspicuous in these coast sections Golden Cap is the intersection of an outlier resting on Middle Lias; the next outlier, Stonebarrow Hill, overlies the junction of the Middle with the Lower Lias; the Black Ven Gault rests on the upper beds of the Lower Lias, and the larger tract west of Lyme passes across the rest of the Lower Lias and across the Rhætic Beds till, in the fine cliff at the mouth of the River Axe, it is seen to lie directly on the red marls of the Triassic Series.

The coast sections near Lyme and Axmouth have been visited by many geologists, and many opinions have been expressed with regard to the age and correlation of the beds seen in them.

The earliest description of them is that of Sir H. De la Beche in 1826[1]; he gives a good general account of the succession near Lyme Regis, and of the Whitecliff section near Beer. He speaks of the beds as "Greensands below the Chalk," and does not specially compare them with the 'Greensands' of more eastern counties.

Dr. Fitton, whose memoir was published in 1836,[2] gives a brief account of the same sections, and expresses his belief that they

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[1] Trans. Geol. Soc., Ser. 2, vol. ii. p. 113.
[2] Trans. Geol. Soc., Ser. 2, vol. iv. p. 233.

include representatives of both the Lower and Upper Greensand. "The Gault," he says, "has wholly disappeared, but some of its characteristic fossils are found in the sand and grit of the cliffs to the west of Lyme." He thought the Lower Greensand was much reduced in thickness and had coalesced with the Upper Greensand, and this view remained in vogue for a long time.

In 1842 Mr. Godwin-Austen came to the conclusion that the basement-beds of the Devonshire Greensand were probably "a sandy condition of the Gault,"[1] a sound conclusion which is confirmed by all the latest observations and enquiries. Many subsequent writers, however, have been very loth to give up Fitton's idea that the Lower Greensand was represented in the Devonshire sands. It was for a long time thought that many of the Blackdown fossils were Lower Greensand species, but at the present time it is doubted whether any species are common to the two formations, and certainly none of the specially characteristic Lower Greensand species occur in the Blackdown Beds or in the basement-beds on the coast.

The publications of Mr. C. J. A. Meyer illustrate the gradual progress of opinion on this point. Writing in 1863,[2] and again in 1866,[3] he expresses his belief in the presence of the Lower Greensand on the Devonshire coast, but in 1874[4] he states his opinion in less positive terms, and adds the following observation: "It is only fair to say, however, that the palæontological evidence then chiefly relied on has proved far from satisfactory." At the present day he admits the existence of Gault near Lyme Regis, and has finally relinquished the view that anything older than such Gault exists among the Cretaceous Rocks of Devon.

The divisions recognised by De la Beche were in descending order (1) Chert Beds, (2) Foxmould, and (3) Cowstone Beds, but he did not recognise the representative of (4) the Gault which underlies the Cowstones. The zonal age of the Devonshire Gault is a little doubtful, but it probably belongs to the upper part of the Lower Gault; the Cowstone Sands and the Foxmould certainly represent the Upper Gault or zone of *Ammonites rostratus*. In describing the section it will be convenient to take the three lower sub-divisions together, and to give a separate account of the Chert Beds.

Stratigraphical Details.

Gault and Foxmould Sands.

Golden Cap is a hill which has been bisected by the erosion of the sea. North-east of it and connected by a narrow strip of Gault clay and sand is another hill of nearly the same height called Langdon Hill, and further inland is Hardown Hill, which

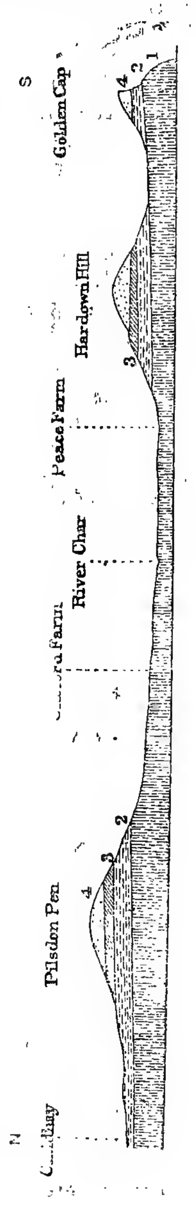
[1] Trans. Geol. Soc., Ser. 2, vol. vi. p. 449.
[2] Geologist, vol. vi. p. 60.
[3] Geol. Mag., vol. iii. p. 13.
[4] Quart. Journ. Geol. Soc., vol. xxx. p. 382.

rises to 677 feet, and is capped by a mass of chert gravel and slipped masses of the Chert-beds.

Fig. 61 shows the manner in which these outliers come in.

FIG. 61.—*Section from Pilsdon Pen to Golden Cap, Dorset.*[1]

Horizontal Scale, an inch to a mile, Vertical Scale about 2000 feet to an inch. *See* also the map on p. 13.



4. Gault and Upper Greensand.
3. Midford Sands and Upper Lias.
2. Middle Lias Sands.
1. Middle and Lower Lias Clays.

[1] Geol. Mag., 1898, p. 166.

The front of Golden Cap cliff presents a good section of the lower part of the Selbornian, and the base is not difficult to reach if descent is made from the top of the cliff on the eastern side of the hill. There is a thin capping of chert gravel on the

highest part of the hill, and below this are soft yellow and greenish glauconitic sands, often in stripes or bands of yellow and green, the green having more glauconite than the yellow. The thickness of this sand is probably 100 feet, and it rests on the topmost bed of the following series which was measured in 1896:—

	Feet.
Dark grey sandy clay with Gault fossils - -	6
Grey glauconitic sand passing down into grey argillaceous sand	12
Dark grey sandy clay, the lowest six inches containing small pebbles of quartz and lydianite - -	6
Soft yellowish-brown sand with a layer of pebbles at base about two inches thick -	2
Soft yellow sand, with some glauconite grains -	2½
Bed of pebbles in sandy clay, resting on Lias - - - -	1

The fossils found in the upper bed of clay were *Pecten orbicularis, Lima parallela, Cucullæa glabra, Pinna* (fragment) and *Lingula subovalis.* Mr. De Rance[1] has recorded *Nucula, pectinata, Pinna tetragona, Inoceramus concentricus* and *Neithea quadricostata.*

Having washed a sample of the lowest pebble-bed I found it consist mainly of different varieties of quartz, with some fragments of black and grey chert and lydianite.

Out of 100 pebbles the proportion was as follows:—

Yellow quartz and (?) quartzite	60
Clear white quartz	30
Quartz with tourmaline	2
Chert and lydianite - - -	8

The clear quartzes are mostly small, about the size of swan shot; the larger pebbles are of yellow quartz and chert, most of them angular or subangular, as if they had not travelled far; these are an inch or more in length, but the smaller ones are rounded. Some of the largest chert fragments were sent to Dr. Hinde who found that several contained traces of Radiolaria, and were similar to the Culm-measure cherts near Dartmoor.

The overlying yellow sand is of fine grain, and a washed sample was found to consist mainly of small quartz grains, with a few larger ones, some of which are red carnelian; there is also a fair sprinkling of dark green glauconite grains, and a few flakes of mica.

The next cliff exposure is in the face of Black Ven, where the lower beds are easily accessible, and fresh exposures are frequently laid open by the slipping of the Lias cliff below. The succession here has been described in a general manner by Mr. C. E. De Rance in 1874[2] and by the Rev. W. Downes in 1885.[3] Neither of these

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[1] Geol. Mag., Dec. 2, vol. i. p. 226. [2] Op. cit.
[3] Quart. Jour. Geol. Soc., vol. xli. p. 23.

writers, however, seems to have realised the great thickness of the sands at this place, and it is a difficult section to measure, because the exposures are disconnected and separated by slopes and boggy hollows.

Visiting the place in 1895, with the advantage of having the contoured six-inch map in my hands, I found a good exposure of the Gault *in situ* at a spot very little above the 300 feet contour-line, and could identify the yellow sands with obscure impressions of shells in which Mr. Downes found his Blackdown fauna, just above the roadway at a height of about 425 feet. This spot therefore, instead of being 50 feet above the place where he found Gault fossils, is at least 100 feet, and there is another 30 or 40 feet of sand above capped by chert gravel. This gravel, moreover, comes down to a lower level on the eastern spur of the hill than at the western end, where there is a quarry showing gravel overlying sand at the 500 feet contour, while the base of the Gault seems to be about 180 feet below. The full thickness of the sands and sandy clays below Timber Hill, as it is called on the Ordnance maps, may be taken at 180 feet, and in order to calculate the total thickness of the Selbornian at this place, we must add the probable thickness of the Chert-beds, for which 40 feet is a low estimate.

Not only is there no exposure of Chert-beds in place, but I could not find any trace of the hard glauconitic sandstone which underlies them both in the country to the north and in that to the west. The highest visible bed is a brownish sand with green grains and many broken shells of *Pecten* (*Neithea*) *quadricostata*, recalling sand seen at Foxdon, near Chard (*see* p. 181).

Below this comes the usual yellowish grey sand or Foxmould, and in it at a spot about a mile and a quarter from Lyme Regis, and just above the roadway, is the sand described by Mr. Downes; portions of it are sufficiently tenacious to require splitting with a knife, and these contain impressions of fossils, among which I could recognise *Cardium hillanum*, *Cytherea caperata*, *Cyprina cuneata*, *Gervillia solenoides*, and a *Trigonia*, with *Ostrea canaliculata* and *Exogyra conica* as shells.

Mr. Downes was fortunate enough to find a nest of silicified but fragmentary fossils here, which he describes as resembling very poor Blackdown specimens. Among them he identified the following species:—

Cyprina cuneata (abundant).	Cardium proboscideum.
Gervillia rostrata (abundant).	Pecten orbicularis.
Cytherea caperata.	Neithea quinquecostata.
Trigonia scabricola.	Turritella granulata.
Cucullæa glabra.	Phasianella ?
" var. fibrosa.	Serpula.
Exogyra, sp.	Siphonia.

Below the level of the roadway there is no continuous section, but at the end of a promontory below the west end of the

Charmouth cutting there is a good exposure, where the following succession was measured:

		Feet.
Part of Foxmould.	Yellowish sand, weathered at top, - about	20
	Greenish-grey glauconitic sand with scattered calcareous concretions of the same colour enclosing *Serpula (Vermicularia) concava, Exogyra conica*, and casts of bivalves, - - about	30
Cowstones -	Layer of compact greenish grey calcareous stones (upper layer of cowstones) - -	1
	Soft brownish-grey glauconitic sand - -	12
	Layer of cowstones lying irregularly in brownish grey sand, *Serpula (Vermic.) concava*	3
	Grey micaceous sand -	5
	Lowest layer of cowstones, very hard, compact, and dark grey, often 3 or 4 feet wide, and up to a foot in thickness - -	1
Gault -	Darker grey sand enclosing patches and veinings of dark argillaceous matter, passing down into micaceous sandy clay, *Serpula (Vermic.) concava* common about	10
	Nearly black micaceous sandy clay, with many fossils in a friable condition, about	5
	Stiff greenish-black sandy clay, with patches of brown ferruginous sand, fossils -	2½
	Dark green glauconitic sand (2½ feet), passing down into greenish-black argillaceous sand (3 or 4 feet), very wet, and base not seen -	6
		95½

Springs issue from this wet argillaceous sand, and there is probably another foot of such material before reaching the Lias. Hence the beds referable to the Gault are about 25 feet thick. The beds which contain large "doggers" of the true "cowstone" type are not more than 20 feet thick, but De la Bèche and others seemed to have grouped with them the overlying greenish sands which contain smaller, less hard, and lighter coloured concretions. There is a complete passage from one portion to another, and no separation of the Cowstones from the Gault by any layer of light coloured sand.

The lower layers of "Cowstones" are very hard, compact, and difficult to break, and I could not ascertain from which set or layer most of the fossils have been obtained. The following list of fossils from these beds is taken from the paper by Mr. De Rance above quoted, with one or two additions and alterations :—

Cardiaster latissimus *Ag.*
Podopilumnus Fittoni, *McCoy.*
Necrocarcinus Bechei, *Desl.*
Hoploparia longimana, *Sow.*
Orithopsis Bonneyi, *Carter.*
Cardium gentianum, *Sow.*
Lucina pisum, *Sow.*
Lima semisulcata, *Sow.*
Inoceramus concentricus, *Park.*
Modiola, new sp.
„ reversa, *Sow.*
Pinna tetragona, *Sow.*
Cucullæa glabra, *Park.*
Venus immersa, *Sow.*
Trigonia aliformis, *Park.*
„ scabricola, *Lyc.*
Cytherea plana, *Sow.*
Thetis Sowerbyi, *Röm.*
Pleuromya mandibula, *Sow.*
„ plicata, *Sow.*
Tellina inæqualis, *Sow.*
Turritella granulata, *Sow.*
Pleurotomaria Rhodani, *d'Orb.*
Ammonites splendens, *Sow.*

This fauna certainly connects the beds with those of Blackdown and with the micaceous sandstone of Devizes, for most of the species occur at those localities, and many also in the Upper Gault of Folkestone.

The bed from which the Gault fossils have been obtained is evidently the band of dark grey, nearly black, clay, which is about five feet thick; *Lima parallela* is very abundant, and I also found *Pecten orbicularis, Inoceramus concentricus* and *Pleuromya mandibula* in a very short search. The following is a complete list based on that given by Mr. De Rance, corrected and supplemented by the Catalogue of the Cretaceous Fossils in the Museum of Practical Geology:—

Hemiaster asterias, *Forbes.*

Anatina sp.
Anomia sp.
Arca (Cucullæa) carinata, *Sow.*
Avicula sp.
Corbula sp.
Cytherea truncata, *Sow.*
Gervillia linguloides, *Forbes.*
Inoceramus concentricus, *Park.*
Lima parallela, *d'Orb. non Sow.*
Lucina tenera, *Sow.*
Modiola sp.
Nucula bivirgata, *Sow.*
„ ovata, *Sow.*
„ pectinata, *Sow.*
„ sp.
Pecten orbicularis, *Sow.*
„ sp.
„ (Neithea) quadricostatus, *Sow* (small var.).
Pholadomya fabrina, *Ag.*
Pinna tetragona, *Sow.*
Pinna, sp.
Pleuromya mandibula, *Sow.*
„ plicata, *Sow.*
Solen dupinianus, *d'Orb.*
Thracia sp.
Venus sublævis, *Sow.*

Actæon affinis, *Sow.*
Aporrhais orbigniana, *P. and R.*
„ (Ornithopus) retusa, *Sow.*
„ histochila, *Gard.*
Cerithium trimonile? *Mich.*
Scalaria dupiniana, *d'Orb.*
Fusus clathratus, *Sow.*
„ elegans, *d'Orb.*
„ rusticus, *Sow.*
Natica Genti, *Sow.*
Turritella vibrayeana, *d'Orb.*
Dentalium decussatum, *Sow.*

Ammonites splendens, *Sow.*
Hamites sp.
Saurocephalus (tooth).

Out of the 30 named species in the above list 24 are found in the Lower Gault of Folkestone, which seems to be a sufficient indication of the general age of the deposit, while the absence of any of the varieties of *Ammonites interruptus* seems to indicate that it is above the basal zone characterised by that fossil.

A sample of the Black Ven clay was sent to Mr. F. Chapman, A.L.S., who has kindly extracted and named the following microzoa (the letters c., v.c., f., r., and v.r. indicate common, very common, frequent, rare, and very rare):—

Foraminifera.

Anomalina ammonoides, *Rss.*, v.c.
„ complanata, *Rss.*, f.
Cristellaria Bronni, *Rœm*, r.
„ circumcidanea, *Berth.*, r.
„ gaultina, *Berth.*, f.
„ gibba, *d'Orb.*, r.
„ linearis, *Rss.*, v.r.
„ rotulata, *Lam.*, c.
„ macrodisca, *Rss.*, f.
„ subulata, *Rss.*, f.
„ Schlœnbachi, *Rss.*, v.r.
„ turgidula, *Rss.*, r.
Haplophragmium emaciatum, *Brady*, c.
Haplophragmium æquale, *Röm.*, v.r.
„ nonioninoides, *Rss.*, r.
Gaudryina dispansa, *Chap.*, v.r.
Marginulina æquivoca, *Rss.*, v.r.
Nodosaria paupercula, *Rss.*, r.
„ tenuicosta, *Rss.*, r.
Pulvinulina reticulata, *Rss.*, c.
Trochammina concava, *Chap.*, v.r.
Vaginulina arguta, *Rss.*; v.r.

Ostracoda.

Cythere Harrisiana, *Jones*, var. setosa, *J. & H.*, v.r.	Cythereis quadrilatera, *Röm.*, v.r.
Cythereis ornatissima, *Rss.*, r.	Cytheridea perforata, *Röm.*, v.c.
„ var. reticulata, *J. & H.*, r.	Cytherella Muensteri, *Röm.*, v.r.
	Pontocypris bosquetiana, *J. & H.*, v.r.

Mr. Chapman also made a rough analysis of the clay with the following result:—

Argillaceous matter -	75 per cent.
Calcareous „ - -	22 „
Arenaceous „ - -	3 „

The occurrence of glauconitic sand below this Gault clay is interesting; it consists entirely of glauconite and quartz, and it passes down into more argillaceous material, which, however, still contains much glauconite. My colleague, Mr. C. Reid, informs me that in 1875 he saw an exposure showing the actual base and junction with the Lias, the succession being:—

	Feet.	*Inches.*
Dark blue glauconitic sandy loam -	6	
Layer of small pebbles mixed with clay, containing fish teeth and derived Lias fossils - - - -	0 to	6
Sandy clay containing many worm tubes (Disturbed Lias) - - - - - - - - - -		6
Lias clay below.		

He washed a sample of the pebble bed, and found the following rock-ingredients [1]:—

	Feet.
Quartz pebbles -	157
Chocolate-coloured jasper -	61
Black grit - -	25
Black trap, finely vesicular	3
Doubtful but all siliceous	41
Fish teeth -	3
	290

It is doubtless the existence of this pebble-bed, which evidently varies much in thickness, and may in places be over 12 inches, that has given rise to the supposition that a representative of the "Carstone" or Lower Greensand was present at Black Ven. There is no evidence whatever to warrant such an assumption and it may safely be regarded as merely a pebbly basement-bed of the Gault.

Passing now to the west side of Lyme Regis, the yellow (Fox-mould) sands are exposed at the eastern termination of Ware cliff, and traces of the grey sands with "Cowstones" can be seen a little lower above the Cement Works.

Mr. De Rance states (op. cit.) that the Gault occurs at Pinhay, and it is very probable that he saw it in the ravine or water-

[1] *See* Proc. Geol. Assoc., vol. xi., p. xxxviii.

course called Pinhay Dike. In 1895 it was well exposed on the shore in front of Humble Green below Whitland's Cliff, having been pushed downwards and outwards by successive landslips, which have completely broken down the Lias cliffs at this place. A long mass of Gault was seen consisting of very dark grey clay, passing down into greenish sandy clay, precisely like the beds at Black Ven. Near by also were slips of grey micaceous sand and numbers of large "Cowstones," some of them five or six feet long.

Near Corbin Rocks, below the western end of Dowlands cliffs and between slipped masses of the Chert-beds, there are tracts of dark grey argillaceous greensand with *Exogyra conica* and inter-bedded layers of hard, fine-grained grey calcareous sandstone full of *Serpula* (*Vermicularia*) *concava*. These sands appear to be equivalent to the highest part of the Foxmould, and one mass shows their junction with the Chert-beds, the succession here being as follows:—

	Feet.	Inches.
Sand with brownish cherts	–	–
Seam of dark green glauconitic sand with some calcareous lumps	–	3 to 4
Buff coloured sandstone with green grains and some irregular lumps of chert	4	–
Rough nodular green calcareous sandstone, in softer and harder portions ; *Radiopora ornata* and some fragments of shells at the top	2	–
Soft dark green glauconitic sand - seen for	1	–

At another place a little further west there is a still more complete section of these junction beds with 20 feet of glauconitic sand below (see p. 192).

Gault clay can be seen just above the shore below the western end of the great (Bindon) landslip, where the issue of a spring has made a gully down to the beach.[1] It appears to be in place and rests on the Rhætic Beds, for a junction can be laid bare showing a hard cream-coloured flinty limestone overlain directly by black glauconitic sandy clay. There is no pebble-bed at the base here, but the clay includes small rounded bits of the limestone and some lumps of green material. The black clay passes up into dark grey sandy clay, from which springs issue, and there would seem to be about 16 feet of this dark clay.

At a height of 12 feet above the main spring there is glauconitic sand, then sandy clay with yellow patches passing up into dark grey glauconitic sandy clay at 16 feet. Looking up the slope above this point, there seems to be over 20 feet of grey sandy clay, succeeded by lighter grey sand containing large rounded doggers like Cowstones. I could not find any fossiliferous band in this section.

The basement-beds can sometimes be seen below Haven Cliff, near the mouth of the Axe, where they rest on the red marls of the Trias, but there was no good exposure at the time of my visit,

[1] *See* Conybeare and Buckland, *Memoir on Landslips*, 1840, p. 6 ; also *Proc. Geol. Assoc.*, vol. xvi., p. 135.

only of the overlying beds, grey argillaceous sand with "cow-stones"; so that I have not been able to ascertain whether the stiff Gault clay reaches to the end of this cliff.

Upper Greensand (Chert-Beds).

Wherever the capping of Chalk has been completely removed from the tracts of Upper Greensand, the Chert-beds seem to have yielded very rapidly to the disintegrative effects of rain, frost, and percolating water. The coast sections of Golden Cap and Stone-barrow show some thickness of chert gravel, and the quarries on Hardown Hill show layers of chert which seem to have settled down in mass, while much of the intervening sand has been carried away, probably it has been gradually washed out by the soakage of rain and the suck of the springs which issue at various points round the hill.

The high ground above Black Ven is similarly capped with the disturbed and broken-up remnants of the Chert-beds. The angular gravel, formed by the action of rain and frost on the cherts, slips down the brow of the hill and is exposed in the pits at the south-western corner (Timber Hill), where it is broken up for road-metal. Very large blocks of chert are often found here which could hardly have travelled in any other way than by slipping with the "wash of the hill."

It is only to the west of Lyme Regis, and round the outlier of Chalk which extends inland between Lyme and Axmouth that the Chert-beds are preserved in a comparatively unaltered condition. In the cliff-section they come in just south of Ware Farm, but are almost entirely concealed by falls of Chalk and gravel, and the first clear exposure is at Pinhay (or Clevelands as the house is now called). This exposure is in a dell or hollow below the cliff, to the west of the valley, and it shows the following beds:—

		Feet.
	Base of Chalk, a hard shelly and sandy limestone with brownish stains, fossiliferous and piped into cracks of the underlying sandstone; 6 to 8 inches	$0\frac{1}{2}$
Upper Greensand	Calcareous sandstone, very hard and calcified in upper two feet, passing into softer yellowish sandstone with cherts in lower part	12
	Bedded sandstone without cherts	8
	Sandstone with irregular scattered masses of grey chert, seen for	10
		$30\frac{1}{2}$

The same beds can be seen in the freshly parted slip at the west end of Pinhay cliffs, and in the cliff below the coastguard station at Whitlands, but they are not easy to reach and the lower beds are obscured by talus. At Whitlands *Exogyra digitata* and *E. conica* occur in the sandstones. The upper 36 feet are also exposed in a quarry by the cliff-path at Rousdon.

The most complete and accessible sections, however, between Lyme and Axmouth are to be found in the great landslip of the

Bindon cliffs; the lower beds with brownish cherts and large calcareous concretions can be seen at the west end of Dowland's cliff, and in the slipped masses which form the shore-cliffs between Corbin Rocks and Culverhole Point. A conspicuous mass in these cliffs showed the following succession in 1897:—

		Feet.
Chert Beds	Sandstone, apparently without cherts, but not accessible	? 6
	Buff coloured sands with many layers of grey and brown chert	? 30
	Seam of dark green glauconitic sand, a few inches.	
	Buff calcareous sandstone with irregular lumpy black cherts	$2\frac{1}{2}$
	Yellowish sugary calcareous sandstone, with some imperfect cherty patches	1
	Soft dark green glauconitic sand	$0\frac{1}{2}$
Greensands	Hard nodular glauconitic calcareous sandstone, weathering brownish	$1\frac{1}{2}$
	Green glauconitic sand with small calcareous lumps. *Exogyræ* at the top	2
	Hard grey glauconitic calcareous stone	$1\frac{1}{2}$
	Dark grey glauconitic sands, seen for	20
		About 65

It is noticeable that the summit of the grey glauconitic sands is marked by two layers of hard greenish calcareous stone. This and the spot near Corbin's Rocks (*see* p. 190) are the first places where the actual position of these beds is well shown, though fragments of them occur further east, and they are probably continuous from Ware to Axmouth. In Whitecliff and the sections to the westward they form one bed of speckled calcareous sandstone.

The higher portion of the Chert-beds is well exposed along the northern wall of the ravine formed by the great Bindon landslip (see Plate, view looking eastward). In this the following section was measured in 1894:—

Section at Bindon.

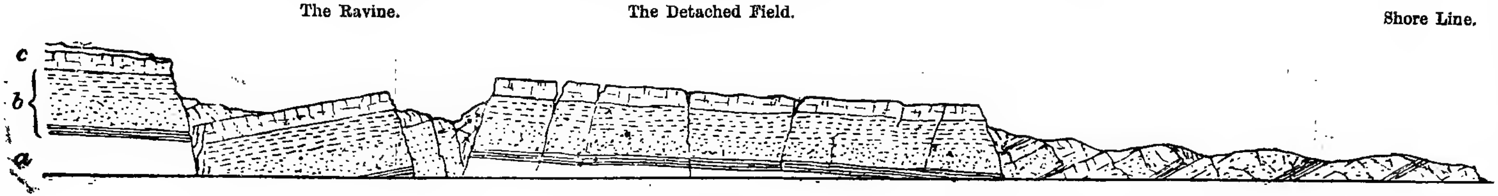
	Feet.
Hard rough calcareous sandstone with some glauconite passing down into less hard and more bedded sandstone	10
Lenticular layers of brown chert in soft yellowish sand	8
Buff-coloured glauconitic sandstone, with a layer of brown chert at the base	2
Rough nodular calcareous sandstone, with a layer of flat sandstone pebbles at the base	2
Irregularly bedded sandstone, with a few lenticular masses of chert in the middle	8
Buff-coloured sand and sandstone, with frequent layers of grey chert and some large lumps or burrs of calcareous stone in the lower part	20
Buff sand with calcareous burr-stones, some lumps of white siliceous stone, and a few of grey chert, seen for	8
	58

Lenticular layers of hard waterworn pebbles of glauconitic sandstone mingled with broken *Exogyra* shells occur at several horizons; the pebbles resemble some of the harder sandstones of

The Landslip at Bindon, near Axmouth.

FIG. 62.—*Section across the Bindon Landslip.*

HORIZONTAL SCALE, one inch to 75 yards. VERTICAL SCALE, one inch to 600 feet.



c. Lower Chalk.
b. Upper Greensand and Gault.
a. Rhætic Beds and Keuper Marls

The section is drawn on the assumption that the detached field has slid forward, and that a large mass has subsided into the gap or ravine this created. It is possible that the Keuper Marls did not partake in the movement, the Chalk and Selbornian together moving over the Rhætic Beds, but this is not certain.

the group, and seem to be portions of such beds rolled and worn *in situ* by the action of strong currents on the sea floor.

The lower 28 feet probably correspond with the 30 feet of chert beds seen in the shore-cliff section, and the total thickness of this group including the topmost sandstone is probably between 60 and 66 feet.

Fossils are not common, but occur sporadically here and there; the cherty beds yield little else than species of *Exogyra*, but from the highest calcareous sandstone the following fossils were obtained by Mr. Rhodes and myself:—

List of Fossils from Calcareous Sandstone, Bindon.

Caratomus rostratus.	Rhynchonella dimidiata.
Catopygus columbarius.	,, Schlœnbachi.
Cidaris (spine).	Terebratella pectita.
Discoidea subucula.	Terebrirostra lyra.
Echinobrissus lacunosus.	Ostrea frons?
Hemiaster sp.	Exogyra conica.
Holaster lævis.	Pecten (a fragment).
Salenia gibba.	Trigonia crenulifera.

In blocks on the shore below Whitlands I found some of the above species and two specimens of *Terebratula ovata.*

The number of small Echinoderms in this list is especially noticeable, recalling those of the Warminster Greensand, and the Brachiopoda are also species found at Warminster and in the calcareous grit of Chard (*see* p. 179).

WHITECLIFF, SEATON.

Beer Head in the distance.

CHAPTER XIV.

GAULT AND UPPER GREENSAND (SELBORNIAN) IN SOUTH DEVON.

THE COAST FROM SEATON TO SIDMOUTH.

This tract of coast is the continuation of that just described. The country behind it consists of a series of ridges and plateaus, trenched by deep valleys, most of which are cut down through the Greensand into the Triassic marls and sandstones. The cliffs present a series of transverse sections through these ridges, and are separated by gaps where the valleys open on to the sea.

Between Seaton and Branscombe there is a synclinal or periclinal flexure which carries the top of the Upper Greensand to about the level of low-water mark at Beer. Whitecliff shows the Greensand overlain by Chalk dipping to the S.S.W. below Beer; thence to Beer Head only the top beds are seen at the base of the Chalk cliffs, but on the west side of that headland the beds rise rapidly westward, and the whole thickness of the Gault and Greensand (about 170 feet) comes into the cliffs east of Branscombe. West of this there is a gradual and steady rise towards Sidmouth. Pursuing the plan adopted in the previous chapter we shall, for the convenience of description, divide the Selbornian group into a lower and an upper division.

Stratigraphical Details.

Upper Greensand (Lower Division).

The formation does not include anything that can be called a clay in this part of its range, but I see no reason to doubt that the Gault of Lyme Regis is represented in the lowermost glauconitic sands. It is true that the lower part of the formation (below the Chert Beds) has thinned from 170 feet near Lyme to less than 90 feet in Whitecliff, but as the Gault is traceable nearly to the Axe I think there is a general diminution of thickness, especially as this division seems to become slightly thicker again westward, my estimate of it at Dunscombe Cliff being over 100 feet. At Dunscombe and Sidmouth the lowest beds consist of fine grey sand, and as very few fossils occur it becomes impossible to say whether any representative of the Gault extends so far.

The most complete and most accessible section of the Devon Gault and Greensand is that of Whitecliff, the fine cliff between Seaton and Beer (see Plate and Fig. 63). The New Red Marl which forms the cliffs near Seaton ends abruptly above the little bay called Seaton Hole, and the Cretaceous Sands are brought in by a fault which strikes nearly north and south. From this line of fault the dip is south-west at about 7° or 8°, and the

which were collected by Mr. Rhodes for the Geological Survey in 1894 :—

M. Echinospatagus murchisonianus.	M. Lucina orbicularis.
M. Hemipneustes Greenovi.	M. Inoceramus sulcatus.
R. Serpula (Vermicularia) concava.	M. Pecten orbicularis.
M. " polygonalis.	M. Pectunculus umbonatus.
R. Anatina sp.	M. Trigonia aliformis.
R.M. Arca (Cucullæa) carinata.	M. " scabricola.
M. Cardium hillanum.	M. " spectabilis.
R. Cytherea caperata.	M. Venus immersa.
M. Exogyra undata.	R. Turritella sp.

It is a curious fact that out of these 18 species only three or perhaps four have been found in the Cowstones of Black Ven, but all of them belong to the Blackdown fauna.

The succeeding 52 feet of sands must represent the "Foxmould" of Lyme Regis, but its thickness is here reduced to less than half, and it contains layers or burrs of calcareous sandstone throughout, while at Lyme these only occur in the lower 30 feet, and the sands above are destitute of calcareous matter.

The zone of *Ammonites rostratus* and that portion of the coast-section which corresponds to the Blackdown Beds is terminated by a band of hard calcareous rock, which is very shelly and fossiliferous at its base, but so hard that the fossils are difficult to extract. My observations here are not quite in accordance with those of Mr. Meyer; he does not seem to have seen this bed, or else he has included it in his "sands with irregular concretions," for it directly underlies the bed which he denominates 4c.

Seeing in this bed of shelly glauconitic sandstone the representative of the calcareous and glauconitic stone which underlies the Chert Beds near Chard and in the west of Dorset, I wished to investigate its fauna, but the united efforts of Mr. Rhodes and myself did not produce a very long list, and many specimens being only casts could not be identified. The following is a list of genera and species determined :—

Placosmilia tuberosa (common).	Pecten (Neithea) quadricostatus (very common).
Cidaris (plate and spines).	Lima semisulcata.
Pentacrinus.	Cardium.
Porosphæra.	Opis (?)
Ceriopora papularia.	Cucullæa.
Serpula.	Pectunculus umbonatus.
Terebratella pectita (?)	Cyprina angulata ?
Anomia sp.	Trigonia affinis (= excentrica).
Ostrea frons.	Venus immersa ?
Exogyra conica (common).	Turritella sp.
" columba.	
Pecten Dutemplei.	

All the named species, except the doubtful *Terebratella* are such as may be found at Blackdown, and are sufficient to show that the Blackdown fauna ranges up to this horizon. The most noticeable species is *Placosmilia tuberosa,* which was only known previously from Blackdown.

The next place where this portion of the series is exposed is at the base of the cliffs on the south side of Beer Head and below the Southerndown landslip. The beds here dip eastward, and consequently in going westward we find lower and lower beds rising from the beach. At the west end of "Little Beach" the following are seen below the bright greensand and pebble-bed which forms the base of the Chert Bed group:—

	Feet.
Brownish sandstone passing down into yellow sand - -	$1\frac{1}{2}$
Hard calcareous glauconitic rock full of shells *Pecten* (*Neithea*) *quadricostatus, Exogyra conica, Ostrea vesiculosa,* &c., varying in thickness - - - - from 1 to	2
Bright green glauconitic sand - - - - -	$0\frac{1}{2}$
Yellowish-green glauconitic sand with large lenticular concretions of calcareous sandstone which are dark grey in the centre; many broken shells and much iron pyrites, seen for	8

The shelly rock-bed is evidently the same as that of the Whitecliff section. It can be seen again with about 7 feet of the underlying grey sand at the base of Hooken Cliff below the Coastguard Station; thence it is visible at intervals in the cliffs to its final outcrop on Maynard Cliff, near Sidmouth. The continuation of the Little Beach section is hidden by the débris of the Hooken landslip, but under the rocks known as "The Pinnacles" the sea has eaten through the fallen blocks and exposed yellowish grey sands with large burrs of grey calcareous stone apparently corresponding with the sands which overlie the Cowstone Beds at Whitecliff, and some of the softer burrs yielded the following fossils:—

Serpula (Vermicularia) concava.	Cardium hillanum.
Echinospatagus murchisonianus.	Pleuromya plicata.
Exogyra columba.	Cucullæa (cast).
„ conica.	Cyprina (cast).
Cytherea caperata ?	Trigonia (cast).

Below these beds are grey sands with flattened lenticular layers and floors of grey stone crowded with *Serpula (Verm.) concava.* All the beds are dark grey on the shore where full of water, but as they rise into the cliff they dry to a yellowish-grey.

The continuation of these beds below Hooken Cliffs is much obscured by slips and fallen masses, but they may be traced at intervals, with traces of cowstones and greenish argillaceous sands throwing out springs.

At the western end of the undercliff near Branscombe Mouth

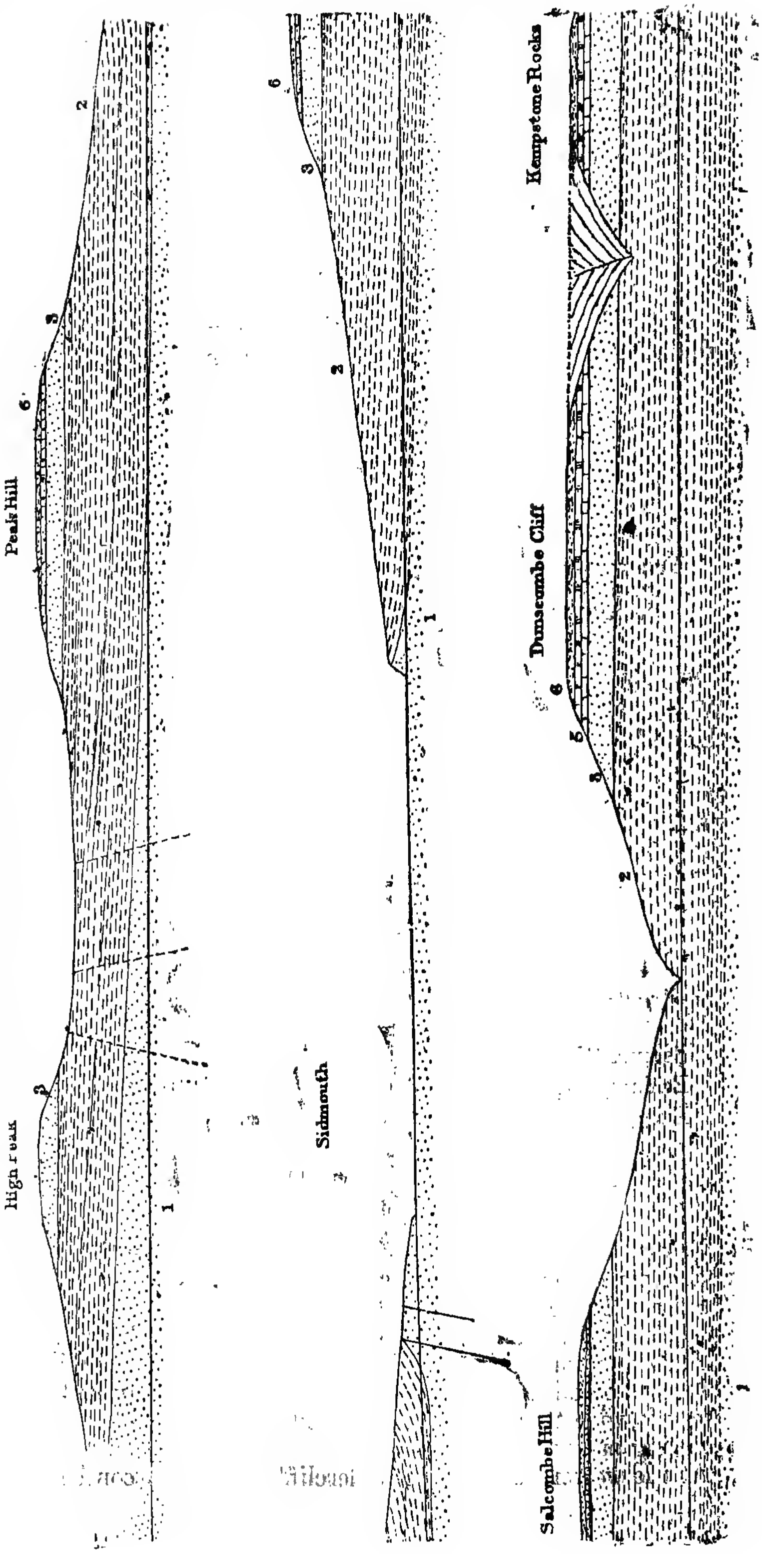
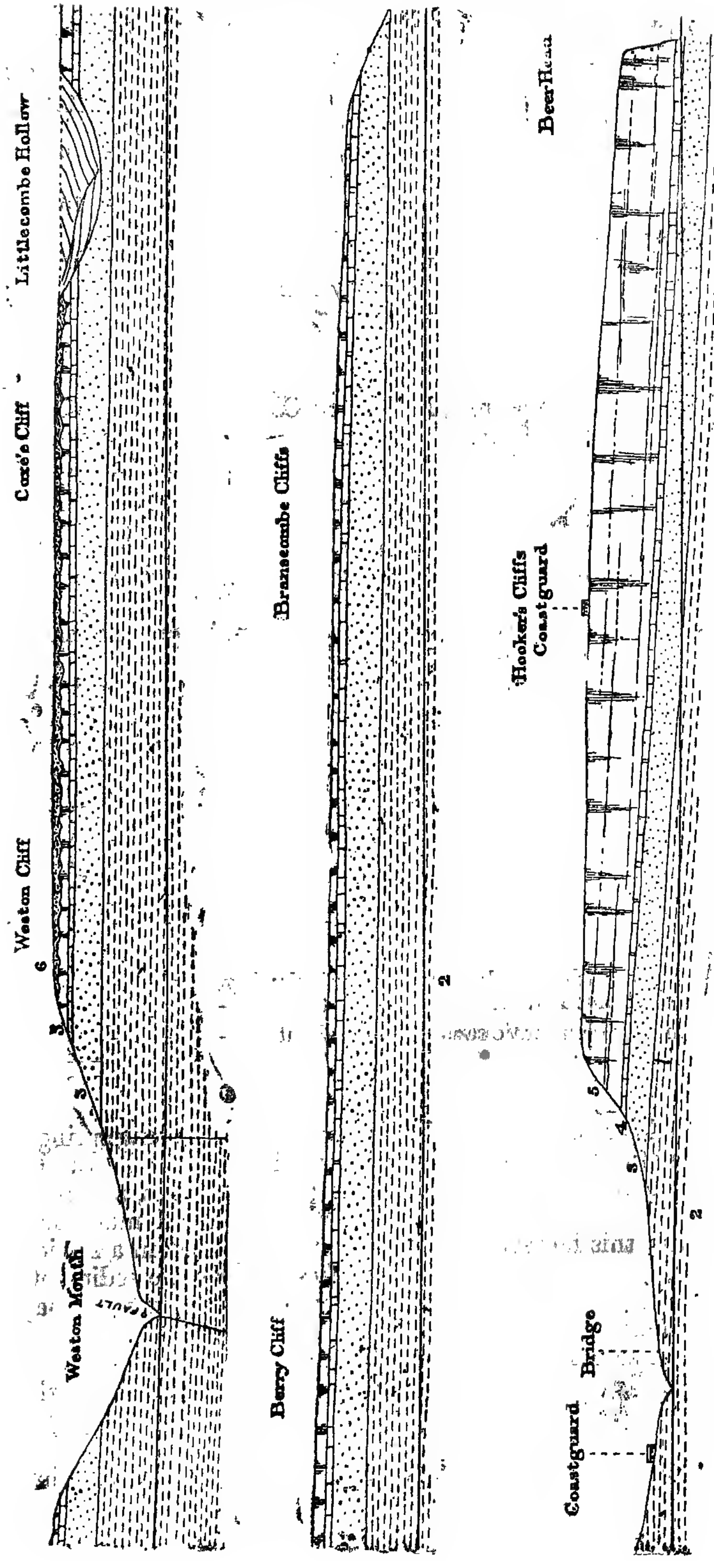


FIG. 64.—*Section of the cliffs from High Peak near Sidmouth to Beer Head.* (A. STRAHAN AND A. J. JUKES-BROWNE).
HORIZONTAL SCALE, 7 inches to a mile. VERTICAL SCALE, one inch to 900 feet.



6 Superficial Drift (gravel, &c.)
5 Middle Chalk, with equivalent of Lower Chalk (4 near Beer Head).

3. Chert-beds, Sandstones, and Greensand. } Upper Greensand (Selbornian).

2. Red Marl
1. Red Sandstone } Trias.

all but the lowest beds can be seen, and the following succession was made out:—

	Feet.
Hard speckled greenish-white glauconitic calcareous sandstone, rough and massive	6
Soft buff-coloured sands with rounded burrs of grey calcareous sandstone - - -	15
Soft bluish-grey glauconitic sands, with some burrs, *Exogyra conica*	18
Soft grey glauconitic sands with nearly continuous layers of calcareous stone, seen for - -	21
	60

Passing over the exposures in Weston Cliffs which are difficult to reach, we come to Kempstone Rocks, near Dunscombe, where the Chert Beds form a fine cliff, at the base of which the shelly glauconitic sandstone is exposed; it consists here of an aggregation of rough calcareous rocky masses with interspaces filled with dark green glauconitic sand, the whole from 5 to 6 feet thick. The fossils occur in patches, *Neithea quadricostata* and *Exogyra conica* being common, with *Exogyra digitata* and *Lima semisulcata.* Lower beds are seen at intervals on the slope below, but are not well exposed (*See* Fig. 63.)

A little further west, however, in Dunscombe cliff, these lower beds are shown in a vertical face above a shelf formed by the projecting outcrop of the Triassic Marls. The following is the succession with rough eye-measurements:—

	Feet.
6. Hard rough greenish calcareous sandstone - - -	6
5. Buff sands with long layers of calcareous stone - -	20
4. Greenish sand with thin layers of siliceous stone in the upper part - - - - - - -	16
3. Greyish sand with a few small doggers of calcareous stone	10
2. Grey sand with large doggers and lenticular layers of fine grey calcareous stone - - - - -	15
1. Clean grey glauconitic sand, seen for about - -	35
	102

The actual base was not seen, but is marked by the strong springs. It will be noticed that the Whitecliff subdivisions can hardly be recognised here; No. 2 may represent the Cowstones, but if so the sands below are thicker than at Whitecliff, and much less argillaceous; this however is what might be expected in a section so far west, and nearer to the source from which the sediments came. The thin layers of siliceous stone in the upper part may be on the horizon of the "whetstones" of the Blackdown Hills.

Mr. Meyer seems to have seen the actual basement-bed here, of greenish argillaceous sand, 3½ feet thick, and taking the thicknesses mentioned in his paper, the total is only 78½ feet, but my estimate must be nearer the truth, for the contours on the six-inch map show that the base of the sand is a little below

the 300 feet line, and the outcrop of the glauconitic rock is a little below the 400 feet, so there must be about 100 feet between them.

The same set of beds can be seen in Salcombe cliff, where about 100 feet of sands come in below the flint-gravel which caps the hill. In the lower 30 feet of these Mr. Meyer found *Serpula* (*Verm.*) *concava*, *Exogyra conica*, and *Cyprina cuneata*; and Mr. Strahan obtained *Trigonia aliformis*, *Cytherea caperata* and *Turritella granulata*.

The last cliff in which any thickness of Upper Greensand is left is that of Peak Hill west of Sidmouth. Here there is about 60 or 65 feet of undisturbed Greensand beneath a thick capping of disturbed sand and flint gravel. I examined the eastern end of this cliff and found the following succession:—

		Feet.
Flint, gravel, and disturbed sand	about	20
Clean buff sand, not reached -	"	10
Buff sand with small irregular siliceous concretions and thin layers of siliceous stone -	"	12
Greyish sand with a layer of friable sandy nodular concretions, containing fossils with silicified shells - -	"	10
Clean light-grey sand weathering yellowish -		30 to 35
Red Marl seen below.		

A fresh slip exposed the actual junction of the grey sand and the Red Marl, and although water was issuing from the sand it was not dark and argillaceous like that at Whitecliff, but quite light grey to the very base. Evidently some considerable change has taken place here; the basement-beds seem either to be absent or much thinner, and if the sands with siliceous concretions are the same as those seen at Dunscombe cliff the beds below are 20 feet thinner, the sand with large doggers having quite thinned out.

In the fossiliferous nodules I found *Cytherea caperatea*, *Pleuromya plicata* and *Petricola nuciformis ?*; and my colleague, Mr. Strahan, has handed me two of these concretions which he obtained many years ago, and from which I have extracted upwards of 60 specimens belonging to 28 species, among which *Cucullæa fibrosa* and *Lucina pisum* are the most abundant. From the same horizon at the western end of the hill Mr. Meyer found many fossils, a list of which is given in his paper.

Near the northern end of the same tract of Greensand, and on the western slope, a little south-west of the point known as Salter's Cross, is a sand-pit from which Mr. Strahan obtained a similar assemblage of fossils, but in a less friable condition, and still more like those of Blackdown. Of these I have been able to identify 36 species, besides several which appear to be undescribed.

The following is a list of the species which have been obtained from the two localities above mentioned, m. indicating the species recorded by Mr. Meyer, and s. those obtained by Mr Strahan and determined by myself:—

	Peak Hill.	Salter's Cross.
Ammonites rostratus, *Sow.*	s	s
„ varicosus, *Sow.*	s	–
Aporrhais (Dimorphosoma) calcarata, *Sow.*	s	s
„ (Ornithopus) retusa, *Sow.*	s	–
„ Parkinsoni, *Sow.*	m	–
Actæon affinis, *Sow.*	s	s
Dentalium medium, *Sow.*	–	s
Fusus quadratus, *Sow.*	m	s
„ rusticus, *Sow.*	–	s
Littorina [Turbo] monilifera, *Sow.*	–	s
Nassa costellata, *Sow.*	–	–
Natica Genti *Sow.*	s	s
„ rotundata, *Sow.*	–	s
„ rauliniana, *d'Orb.* (?)	–	s
Phasianella striata, *Sow.*	–	–
Scalaria dupiniana (?), *d'Orb.*	s	s
„ Fittoni, *Gard.*	–	s
„ new sp.	–	s
Solarium sp.	–	s
Turritella granulata, *Sow.*	s	s
Amphidesma tenuistriata (?), *Sow.*	–	s
Anomia sp.	m	–
Cardium (Protocardium) hillanum, *Sow.*	m s	s
„ (Petricola) canaliculata, *Sow.*	s	–
Corbula elegans, *Sow.*	s	s
„ truncata, *Sow.*	s	s
Cucullæa carinata, *Sow.*	m	s
„ glabra, *Sow.*	s	s
Cytherea caperata, *Sow.*	s	s
Cyprina angulata, *Sow.*	–	s
„ cuneata, *Sow.*	m	–
Exogyra conica, *Sow.*	m s	s
Inoceramus concentricus, *Sow.*	m	s
„ sulcatus, *Sow.*	m	–
Leda lineata, *Sow.*	m s	s
Lucina orbicularis, *Sow.*	m s	–
„ pisum, *Sow.*	s	s
Mactra angulata, *Sow.*	m s	s
Modiola reversa, *Sow.*	s	–
Nucula antiquata, *Sow.*	s	s
„ apiculata (?), *Sow.*	–	s
„ impressa, *Sow.*	m s	–
Pleuromya læviuscula (?), *Sow.*	s	–
Pecten Milleri, *Sow.*	m	–
„ orbicularis, *Sow.* (small)	m s	s
„ (Neithea) 5-costatus, *Sow.*	–	s
Tellina striatula, *Sow.*	m	–
„ inæqualis, *Sow.*	m	s
Thetis Sowerbyi, *Roem.*	m	s
Trigonia aliformis, *Park.*	–	s
„ læviuscula, *Lyc.*	m	–
„ scabricola, *Lyc.*	s	s
„ spectabilis, *Sow.* (young)	s	–
„ spinosa, *Park.* (young)	s	–
Venus sublævis, *Sow.* (or V. faba, *Sow.*)	s	s
Serpula (Vermicularia) concava, *Sow.*	m s	–
Enallaster Grenovi, *Forbes*	m	–
Pseudodiadema sp.	s	–

Upper Greensand (Chert Beds).

This division of the Greensand attains its greatest thickness along this coast. The estimate given by De la Beche (*i.e.* from 70 to 80 feet) is correct, for it has a thickness of 76 feet in Hooken Cliff, and at Whitecliff it is not far short of 70 feet. The group is clearly defined both at the summit and at the base, for I include in it all the beds above the shelly glauconitic sandstone which has been described at the top of the Blackdown Beds or zone of *Ammonites rostratus.* The development of the nodules and masses of chert is remarkably local and irregular; sometimes they occur throughout the whole thickness except the lowest 3 or 4 feet, and in other places there are only 10 feet of sand in which cherts occur, the beds above and below being destitute of any kind of siliceous concretions. Near Sidmouth the cherts are confined to the lower part.

The topmost bed, which varies from 8 to 10 feet in thickness is a calcareous sandstone, which seldom contains cherts, and passes westward into a calcareous sand largely composed of comminuted shell-fragments. It seems to represent the calcareous grit of inland sections, but though it contains some of the same fossils, it is a curious fact that *Pecten asper*, which is so common in the calcareous grit of Eastern Dorset, has not been found at this horizon in Devonshire. *Exogyra digitata* (Sow.) is a common fossil in the sandstones of the chert beds, as was pointed out by De la Beche in 1826, and *Orbitolina concava* is common in places; *Exogyra columba* and *Ex. conica* also occur, but other fossils are rare.

Returning to the fine section in Whitecliff, between Seaton and Beer Harbour (*see* p. 196), where a southerly dip brings each successive bed of the group down to the level of the beach, the highest bed will be found at "King's Hole" passing below the basal beds of the Chalk which form the eastern point of Beer Harbour. To study this section, therefore, it is most convenient to begin at the southern end, and thus to take the beds in descending order. The succession is as follows:—

		Feet.
1.	Hard nodular calcareous sandstone passing down into less calcified sandstone, which contains occasional nodules of sandy chert	8
2.	Yellow sandstone with large brown cherts	3
3.	Soft and rather coarse yellowish-green sand, consisting of quartz and glauconite	1½
4.	Soft yellowish sandstone with lenticular layers of brown chert	4
5.	Hard nodular greenish calcareous sandstone weathering into rough lumps, but less nodular below (*Exogyra digitata* common)	4
6.	Grey sandstone with dark grey cherts, those in the upper part being small	12
7.	Rough shelly sandstone weathering brown, full of single valves of Exogyra	3
8.	Yellowish sand and sandstone with irregular masses of grey chert, those in the upper part very ferruginous; some layers of hard buff calcareous stone near the base	7

9. Grey glauconitic sand with concretions of fine-grained calcareous sandstone - -	3½
10. Grey glauconitic sand with black cherts - -	4
11. Grey sandstone with broken shells and many pieces of a calcareous sponge, and occasional cherts in the upper part - - - - - - - - - -	3
12. Hard grey calcareous sandstone with black cherts - -	3
13. Brownish loamy sand with a layer of large irregular cherts in the middle, and hard calcareous lumps above and below - - - - - - -	5
14. Dark grey glauconitic sand passing into dark-green argillaceous sand with lumps of calciferous sandstone at the base - - - - - - - - -	2
15. Rough nodular greenish-grey calcareous sandstone, enclosing some sandstone pebbles and fossils -	1½
16. Soft green sand with thin grey partings - - - -	1
	65½

All these beds are exposed on the south side of the great débris slope produced by the fall of 1887; to the north of this fall the section is continued with the beds described on p. 197.

Fossils are not abundant in these beds, and the following is a list of all that were found by Mr. Rhodes and by myself, the number above each column referring to the beds as numbered in the above section:—

——	1.	5.	7.	11.	15.
Orbitolina concava	–	x	–	–	–
Elasmostoma sp.	–	–	–	–	x
Cidaris (spines and plates)	x	x	x	–	–
Ceriopora sp	–	–	x	x	–
Radiopora ornata -	–	–	–	–	x
Rhynchonella Schlœnbachi -	x	–	–	–	–
Ostrea frons	–	x	–	–	–
Exogyra columba	–	–	–	x	x
„ digitata - - -	–	x	x	–	
Pecten (Neithea) quinquecostatus	–	–	–	x	–
Lima semisulcata	–	–	–	–	x
Spondylus sp.	–	–	–	–	x
Cardium (cast)	–	x	–	–	–

The upper 20 feet of the Greensand can be seen in the cliff at the back of the little cove called Pounds Pool beach, south of Beer, where they are brought up by a slight anticline. Here, too, there are lumps of clear brown chert both above and below the layer of yellowish-green sand which lies about 12 feet from the top. Close to Beer Head a few large masses of chert still occur above this band, the sandstone passing over them in wavy layers as if uplifted by the formation and growth of the chert; but as the beds are followed round the headland the cherts cease to occur and at the same time begin to die out in the underlying beds, so that above Little Beach, to the west of the Head, there is over 35 feet of sandstone without any cherts, though the lower beds still contain grey and black cherts like those in the corresponding beds of the Whitecliff section.

The Little Beach section is as follows:—

	Feet.
Yellowish bedded sandstone, glauconitic, with thin wavy seams of greenish sand in the lower part -	10
Coarse yellowish-green sand -	1
Hard and rough lumpy calcareous grit - - - -	3
Compact yellowish sandstone, streaked with seams of greensand	6
Massive greenish sandstone, including a layer of sandstone pebbles and broken shells - - - -	8
Pebble-bed consisting of waterworn sandstone pebbles - -	2
Yellowish calcareous sandstone with irregular seams of greenish-grey sand - - - - -	5½
Sandstone with layers of greyish rusty cherts	6
Hard grey calcareous stone and shelly grit full of *Exogyra*	4
Buff sand with black cherts and some calcareous concretions	13
Dark grey argillaceous sand - - -	1
Green glauconitic sand with hollow calcareous concretions and a rough pebbly bed at the base -	5
	64½

The last of these beds rests on the brownish sandstone mentioned at p. 199; it contains *Radiopora ornata*, and evidently represents beds 15 and 16 of the Whitecliff section. There is, in fact, a great general resemblance between the two sections, in spite of the disappearance of cherts and other differences. It will be noticed also that the difference of total thickness according to the measurements taken, is only 1 foot.

This part of the series is exposed again in Hooken Cliff, below the Coastguard Station, where there is a considerable thickness of beds containing water-worn pebbles of sandstone. The succession is as follows:—

	Feet.
Hard calcareous sandstone with wavy bedding in the lower part, and some scattered brown cherts in the lower two feet	12
Coarse yellowish-green sand weathering out into a niche	1
Buff sand of finer grain, irregularly streaked with greenish grey	6
Buff sands weathering yellowish-green, with lenticular lumps of hard calcareous sandy stone and pebbles of similar stone; many broken *Exogyra* shells in the lower part	5
Sand full of pebbles and broken shells at the top, passing down into rough yellowish-green sand, with scattered pebbles and shells of *Exogyra digitata* -	8½
Sand full of pebbles and broken shells - - -	2
Sand with fewer pebbles and shells - -	8
Grey sand with dark-grey cherts and some calcareous concretions - - - - - - -	6½
Whitish-grey calcareous rock, passing down into light-grey glauconitic sand, with hard calcareous lumps; a few scattered cherts - - - - - - - -	3
Light-grey calcareous knotty sandstone, with dark grey and black cherts in regular layers - - -	9
Light-grey sand full of hard irregular calcareous concretions - - 9 inches to	1
Grey sand with lumpy rounded masses of chert	3
Light-grey sand weathering into a niche -	1
Grey sand containing hard grey calcareous lumps with dark-grey centres, the lower part composed chiefly of such lumps	8
Soft grey glauconitic sand with shells - - - -	2½
Hard speckled glauconitic limestone with many shells of *Exogyra columba* and *Neithea 4-costata*, about 3 feet thick.	
	76½

Below this about 7 feet of grey sand with purplish streaks can be seen, which belongs to the lower zone.

It will be noticed that a few cherts reappear here in the highest bed, and that the beds containing pebbles are over 23 feet thick, as compared with 10 feet near Beer Head, and that the total thickness is 10 feet greater. The speckled limestone at the base has already been mentioned as a constant horizon, and another continuous bed is the coarse yellowish green sand 12 feet below the top.

It should be mentioned that this was the place where Mr. Meyer measured his Beer Head section, and the succession above given includes the beds which he numbered 5, 6, 7, 8, 9, No. 9 corresponding with the highest 19 feet of my section.

In the cliffs west of Branscombe it is difficult to find any place where complete measurements can be taken, because the beds are nearly horizontal, and are only exposed in isolated bluffs separated by grassy slopes and patches of cultivated ground. The upper sandstones, however, are frequently exposed, and in some cases the greater part of the cherty group is visible. Chert is not confined to the lower beds of the group, but occurs in a variable way at many horizons up to within 11 feet of the top. The following is a generalised section:—

	Feet.
Massive calcareous sandstone, generally without cherts, sometimes a lenticular layer in lowest foot - - -	11
Coarse yellow quartz-grit, soft and loose - -	1
Yellowish sand and sandstone in irregular layers, with seams of greenish sand - - - - -	10
Yellowish sand, sometimes without cherts, but generally having many large brown cherts in the lower part -	10—15
Hard whitish calcareous sandstone weathering to a rough face -	4—6
Shell-bed, of *Exogyra columba* chiefly -	1
Yellow sand with irregular layers of grey chert -	6
Yellowish-white sand, with lumps of hard calcareous stone, a little glauconite, seen for - - -	8
	About 55

The bed of hard whitish stone about 35 feet from the top is a conspicuous and continuous bed all along these cliffs. Fossils, except *Exogyra*, are not common, but in Weston cliffs *Orbitolina concava* occurs in the sands above the whitish stone.

Above Weston Mouth coast-guard station the upper part of the cliffs has receded for a space, leaving a long slope backed by a nearly vertical cliff, which is known as Kempstone Rocks.

This affords an admirable section of the Chert Bed group, which can be measured without difficulty, and is as follows:—

Section at Kempstone Rocks, Dunscombe.

	Feet.
Lower Chalk—Cenomanian limestones (4 feet thick).	
Rather coarse quartz-grit, calcified and indurated irregularly, passing down into next - - - - -	$2\frac{1}{2}$
Calcareous sandstone consisting mainly of shell-sand, coarse and more quartziferous below - -	8
Very coarse yellowish quartz-sand - - - -	$2\frac{1}{2}$
Fine-grained calcareous sandstone, a consolidated shell-sand	6
Hard rough calcareous and glauconitic sandstone, nodular in the upper 2 feet - -	6
Shell-bed consisting of large broken *Exogyræ* with some sandstone pebbles bored by *Lithodomus* -	1
Greenish-grey sandstone enclosing irregular lumps of hard calcareous stone; many broken shells and *Exogyra digitata* abundant - -	13
Hard rough whitish calcareous sandstone	
Greyish bedded sandstone with a thin layer of waterworn pebbles at the base	$6\frac{1}{2}$
Buff-coloured calcareous sandstone, with lenticular layers of greyish-brown chert, which are thin and platy in the upper part, thicker below	6
Shell-bed, composed of silicified *Exogyra conica*, with occasional lumps of shelly chert, from 1 to -	$1\frac{1}{2}$
Soft yellowish sand, with small lumps of hard calcareous stone	$1\frac{1}{2}$
Buff sand with irregular masses of imperfect chert (opaque and whitish) and some calcareous burrs -	8
Dark-green sand enclosing irregular calcareous lumps and small sandstone pebbles bored by *Lithodomus*	1
Hard calcareous and glauconitic sandstone.	
	$66\frac{1}{2}$

Here again, therefore, there is a great thickness of sandstone (39 feet) without any nodules of chert, and it is especially noticeable that nearly the whole of this sandstone is highly calcareous, parts of it consisting almost entirely of comminuted fragments of shells and other calcareous organisms. Well-developed cherts are confined to a thickness of only seven feet in the lower part of the section, below the whitish calcareous sandstone which is evidently the continuation of that seen in Branscombe cliffs.

It is, in fact, remarkable how continuous some of these beds are, the coarse yellow sand about $10\frac{1}{2}$ feet from the top being traceable all the way from Whitecliff to this section, a distance of five miles. It will be noticed also that the total thickness of the beds has not diminished in this distance; the actual measurements taken, indeed, make them one foot thicker, but the total was not checked by a line measurement.

I cannot correlate the sequence above given with that in Mr. Meyer's paper, except so far that the $7\frac{1}{2}$ feet of sandstone with cherts is his bed 5, and the bed which he refers to No. 10 at Dunscombe is really part of that which he elsewhere numbers as 9.

The calcareous sandstones have been quarried in the combe to the west of this section, and thence they and the underlying beds can be traced along Dunscombe and Manyard cliffs, till they are cut off by the valley of Salcombe Mouth. They have also been quarried at Dunscombe and Salcombe, the calcareous sandstones having evidently been at one time valued as a building-stone, but most of the quarries are now overgrown. They do not appear in Salcombe cliff.

CHAPTER XV.

GAULT AND UPPER GREENSAND (SELBORNIAN) IN DEVONSHIRE (INLAND SECTIONS).

1. Axminster, Honiton, and the Blackdown Hills.

In these inland districts of Devonshire there are few localities where the formation is complete, for there are only a few places where it is protected by outliers of Chalk. Everywhere else the Chert-beds have been so disintegrated and broken up by the action of rain and frost that it is often difficult to say how much is *in situ* and how much should be regarded as a re-arranged surface deposit. Beneath the summits of the hills there may be and probably is in many cases a considerable thickness of undecomposed sands with layers of chert, but on the slopes these beds are almost always masked by slips and by a downwash of sandy loam containing large lumps of chert, often mixed with flints and small waterworn pebbles of quartz and lydian-stone derived from Tertiary Deposits.

The Lower Sands or Blackdown Beds are occasionally exposed on the lower slopes of the hills, in small sandpits or along road-cuttings; but it is only in the north-western part of the district that they contain the siliceous concretions which are fashioned into scythe-stones. In former days large excavations were made in search of these stones, but the industry has greatly declined.

The Blackdown Sands have been estimated at from 80 to 100 feet, and the latter is probably within the mark, for in many places the base of the sand is 200 feet below the summits of the ridges, and there is no reason to suppose the total thickness is less than along the coast.

Axminster.—Commencing with the eastern part of the area, it is interesting to find that the Gault extends some miles inland from Lyme Regis. Thus my colleague, Mr. C. Reid, observed the following beds in the banks of the stream north of Highgate about three miles E.S.E. of Axminster in 1874:—

Mottled green and orange sand.
Blue micaceous loamy clay, full of fossils like those in the Gault of Black Ven.
Olive-green sand.
Stiff blue clay (Lias).

The beds were not exposed with sufficient clearness to allow of their being measured, but he estimated the thickness of the Gault clay to be 10 or 12 feet. The same beds are cut through by several of the streams which rise in Wyld Warren, and Mr. Reid found the clay was everywhere underlain by a thin bed of greensand.

The "Foxmould" Sands are well shown in the road-cutting at Thistle Hill on the road from Axminster to Charmouth, and about four miles from the former place. About 70 feet of fine yellowish glauconitic sand is seen here, capped by a little chert gravel.

Chert-beds, apparently *in situ*, are seen on the same road less than three miles from Axminster; and again in a sort of cliff or escarpment near Bever Grange, two miles east of Axminster. This cliff seems to have been caused by the slipping of a large slice of the hill into the deep valley on its southern side.

Shute Hill, west of Kilmington, is an outlier of Greensand resting on the red Triassic marl; beds which appeared to be close to the base of the sands are exposed behind the house called Loughwood Villa on the main road to Honiton; they consist of fine micaceous grey sand, very wet, and throwing out springs; it is possible there may be a little clay below, but nothing was seen of it.

Shute Hill itself is capped by the Chert-beds, much displaced and broken, covered by an irregular accumulation of chert-gravel. These are largely quarried at the north end of the hill and also in a quarry near the south end above the village o Shute, where the beds seem to be certainly *in situ*.

On the road to Honiton, and nearly four miles from Axminster is a small pit or quarry showing the following beds:—

	Feet.
Clay with flints	3
Grey marly clay with black stains	2 to 3
Coarse yellowish-brown sand with broken Pectens and Oysters and a few perfect *Exogyra conica;* at the base a layer of greensand	7
Yellow sand with irregular lumps of chert, much broken, and stained black by oxide of manganese, seen for	12

The coarse sand is probably re-arranged material derived from the disintegration of the highest calcareous sandstone and coarse grit which is seen on the coast 11 or 12 feet below the top of the Greensand, the original succession here being probably like that at Beer Head.

HONITON.—The best inland exposure of the lower part of this formation is in the railway-cutting which leads to the eastern mouth of the tunnel on the London and South-Western line near Honiton. The clayey beds here seen were referred to the Gault in 1874 by Mr. W. A. E. Ussher.

I visited this cutting in 1897 and found the sides muc talused, and in places trenched, the trenches being filled wit flints to carry off the water; but here and there are sma exposures of sandy clays. About 150 yards from the mouth o the tunnel on the northern bank I saw the following:—

	Ft.	in.
Grey clay, drying light grey	3	0
Thin seam of black clay	0	3
Dark-grey clay	3	0
Greenish glauconitic sandy clay	2	6

A little further west this sandy clay passes down into fine greenish-grey sand, consisting of small grains of quartz and glauconite. Of this about 6 feet was visible. Still nearer the tunnel and at the bottom of the slope is fine grey sand with a seam of coarse white sand not more than an inch thick, and consisting of clear quartz grains.

There is also an exposure of the fine grey sandy clays above the mouth of the tunnel. The beds dip from the tunnel eastward, and I concluded that there is here a considerable thickness of fine grey sands and sandy clays, probably between 40 and 50 feet, without the base being seen. I did not find any fossils, but the late Rev. W. Downes[1] found some shells "in a black marly clay about six feet thick," which is probably the same band as that above noted. The species found were:—*Inoceramus concentricus*, *Pecten* (*Neithea*) *quadricostatus*, *Actæon affinis*, and species of *Modiola*, *Mytilus*, *Tellina*, *Exogyra*, and *Pectunculus*.

These dark grey sands and clays appear to be a local expansion of the beds which occupy a similar position on the coast at Whitecliff and Branscombe.

The tunnel itself is driven through these sands and clays and into the red Triassic Marl which rises up from beneath them. A coloured section showing the beds traversed by the tunnel, and the terminal cuttings is preserved at the Engineer's Office of the L. & S.W. Railway at Exeter, and we are indebted to Mr. Jacomb Hood (the District Engineer) for providing us with a copy, which is deposited at the Geological Survey Office. This section appears to have been constructed partly from five shafts sunk through the ground before the making of the tunnel, and partly from the evidence of the tunnel and cuttings. The section shows that the surface of the Red Marl is uneven, and that the thickness of the dark sandy beds increases from about 37 feet at the eastern end to over 60 feet in the central part, thinning again to 55 feet at the western end.

The shafts show that the succession of deposits and the thicknessés at the several spots are as follows, the shafts being numbered in order from east to west:—

——	No. 5. Feet.	No. 4. Feet.	No. 3. Feet.	No. 2. Feet.	No. 1. Feet.
Clay with cherts and rocky chert at the base	37	54	33	—	—
Sand with cherts	—	—	5	10	7 sandy wash.
Grey sand with springs	62	81	96	95	30
Yellow sand, very wet	18	18	20	18	10
Galt clay, blue and brown	7	7	6	7	7
Black sand	44	50	40	26	24
Layer of white sand	1	1	1	2	1
Sandy clay	10	10	12	12	12
Red Marl	50	30	24	20	4
	229	251	237	189	95

[1] *See* Geol. Mag., Dec. 3, vol. iii. p. 308.

From my personal examination it is clear that what is termed "black sand" in this account consists partly of dark grey sand and sandy clay, but probably there is also some dark green glauconitic sand, which would look nearly black when wet.

The facts thus recorded show that on the highest part of the hill the thickness of clay with cherts and of broken up chert-beds amounts to 54 feet; and some of the sand with cherts is probably a downwash of chert fragments on to the grey sand. Below these deposits there is a thickness of 167 feet of sands and clays in No. 4 shaft and of 162 feet in No. 3 shaft, and if part of the sand with cherts is *in situ* about 20 feet more must be added to the total thickness of the bedded deposits under this ridge. Fig. 65 is a reduction of this section to a more natural scale.[1]

It may be that the great thickness of sands and sandy clays near Honiton is not so exceptional as it seems when compared with the coast sections, for there are other inland places where 140 or 150 feet of such beds seem to come in below the surface deposits. Mr. Meyer has suggested to me that the less thickness on the coast may be due to the pressing out of some of the sand beneath the cliffs by the superincumbent weight of the rocks above, and to the carrying away of sand by the water which issues in springs.

Blackdown.—We now come to the Blackdown Hills and to the old scythe-stone workings, where so many fine fossils have been obtained. The earliest description of these exposures is that by Dr. Fitton,[2] whose account is valuable as a record of their aspect at that time. He says: "The hills which have furnished the greater number of the Blackdown fossils from the western range of the group between Honiton and Wellington. . . . Their [western] escarpment between Punchey Down on the north and Upcot Pen on the south is distinguishable at a great distance by the white line produced by the refuse thrown down from the openings of the scythe-stone pits, the heaps thus formed constituting an almost continuous stripe in the face of the hill."

"The strata which afford the whetstones are about 80 feet below the top of the hill, to which they are parallel. The mines (or 'pits,' as they are called) are driven in direct lines into the hill almost horizontally, and in some cases to considerable distances. The stony masses from which the scythe-stones are

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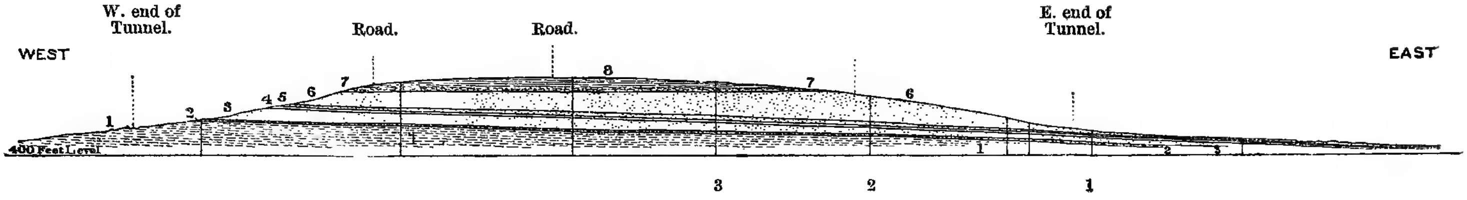
[1] The accuracy of the representation of the bedding on the M.S. coloured section has been impugned by Mr. Downes (*loc. cit.*); but he assumed the rocky chert to be *in situ*, whereas I think it is probably a remnant of the Chert Beds, disintegrated and displaced from having settled down unevenly. The colorist has evidently not quite understood the relations of the surface deposits, and the apparent unconformity is made more conspicuous by the exaggerated vertical scale of the original drawing; but this detracts little from the value of the diagram.

[2] "Trans. Geol. Soc.," Ser. 2, vol. iv. p. 236. Published in 1836, but the observations in Devon appear to have been made in 1825.

FIG. 65. *Section through Honiton Tunnel.*

Reduced from a drawing at the Engineer's Office, L. & S.W.R., Exeter.



Horizontal Scale, 6 inches to a mile.
Vertical Scale, 1 inch to 625 feet.

8 Clay with chert.
7. Chert-band.
6. Grey sands with springs.
5. Yellow sands, water-bearing.

4. Blue and brown clay.
3. Black sand.
2. Sandy clay
1. Red Marls (Keuper).

cut are concretions of very irregular figure embedded in looser sand . . . and though very irregular in shape, marks of the stratification of the sand can be traced on their outside." He describes these concretions as varying from 6 to 18 inches in diameter, and gives a vertical section of the beds then visible in one of the pits, showing that the total thickness of the beds from which material for whetstones was extracted varied from 12 to 18 feet. He also describes the tools used in the preparation of the whetstones.

It is somewhat extraordinary that between the years 1836 and 1880 no more complete account of the Blackdown succession seems to have been published, though the question of their age was discussed by many writers both English and Continental, among whom may be mentioned Prof. Renevier,[1] Messrs. Briart and Cornet,[2] Mr. C. J. A. Meyer,[3] and Dr. Ch. Barrois.[4]

In 1880 the Rev. W. Downes, who had for several years resided at Kentisbere, wrote an account with a full list of fossils, which was published in the Transactions of the Devonshire Association for that year, and in the following year he drew up a more detailed account of the succession with a corrected list of fossils.[5]

Mr. Downes says: "At the present day only three pits are being worked on the eastern side of the ridge, and all have been closed on the western escarpment. Some few of the latter, however, have been open since my residence in the neighbourhood." The ridge referred to is that marked as "Black Down" on the six-inch Ordnance map, and by the eastern side he probably means that part which faces south-east.[6]

Supplementing the evidence derived from the excavations and from the workmen by observations in cart-tracks and road-cuttings, Mr. Downes endeavoured to obtain an idea of the complete structure of the hill, and he divides the Blackdown Sands into twelve beds, describing each from below upwards, and mentioning the fossils which are specially found in each bed.

It will, however, be more convenient for the reader if we give his succession in abstract and in vertical order first, referring afterwards to the special characters and contents of the beds.

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[1] "Bull. Soc. Vaudoise Sc. Nat.," vol. v. p. 51. Abstract in "Quart. Jour. Geol. Soc.," vol. 12, App. p. 21 (1856).

[2] "Description de la Meule de Bracquequies, Mem. Cour. Acad. Bruxelles," Tome 34.

[3] "Geol. Mag.," vol. iii. p. 13 (1866); and "Quart. Jour. Geol. Soc.," vol. xxx, p. 381 (1884).

[4] "Ann. Soc. Géol. du Nord," Tome iii. p. 1 (1875).

[5] *See* "Quart. Jour. Geol. Soc.," vol. xxxviii., p. 75 (1882).

[6] At the present time (1899) only one tunnel is being worked, and this is on the northern slope of the hill. *See* H. B. Woodward, Proc. Geol. Assoc., vol. xvi., p. 143.

The succession at Blackdown (after Mr. Downes) is as follows:—

		Feet.
	Chert gravel capping the hill.	
12.	Sand with layers of cherty sandstone passing upwards into chert - - - - - -	25
11.	Fine variegated sand with thin lenticular and impersistent shell-beds - - -	18
10.	Reddish sand-rock, a stratified sandstone in layers divided by sand - -	3
9.	Thin layer of concretions used for scythe-stones, the "hard fine vein." Only a few inches.	
8.	Sand with *Turritella granulata* -	} 4
7.	Sand with many fossils - -	
6.	Sand with layers of concretions, known as "Gutters" -	5
5.	Layers of concretions separated by sand; these are known as "Burrows" - - -	4
4.	Bed of concretions, used for whetstones, varying in thickness from 6 inches to - - -	5
3.	Grey sand called "Rock Sand" by Fitton, but known as "Bottom Rock" by workmen in 1881	4
2.	A layer of small siliceous concretions, generally only a few inches thick; the "soft fine vein."	
1.	Whitey-brown sand-rock, called "White Rock" by workmen	30
		100

Of the lowest sand Mr. Downes says that it is perfectly homogeneous throughout, and that he found no fossils in it. It is evidently the continuation of the light-grey sand which occupies the same position near Sidmouth (*see* p. 203).

In beds 4, 5, 6 the prevalent fossils are *Trigonia aliformis*, *Inoceramus sulcatus*, and *Pectunculus umbonatus*. Mr. Downes also remarks that "the Ammonites seem to have been found mostly in these lower concretionary beds." He also records *Gervillia anceps*, *Trigonia spinosa*, and *Cardium hillanum*.

Of bed 7, Mr. Downes says that it contains many fossils, *Pectunculus umbonatus* being the commonest, but not ranging higher. *Murex calcar*, with its long slender spines, is also often found perfect in this zone. He remarks that the fossils "are found in clumps, that is to say in clusters or colonies, with valves almost always attached, and with species but little mixed. They have evidently been deposited in still water, and are apparently in the habitat in which they lived and died." Many species occur first in this bed and range upward.

Bed 8 "is also very fossiliferous, and the conditions are the same as those just mentioned. The prevailing fossil is *Turritella granulata* in 'clumps.' Sometimes the clumps consist wholly or mainly of Turritella, sometimes they are mixed with *Aporrhais calcarata* and *Ap. neglecta*." *Siphonia pyriformis* seems to be peculiar to this bed. *Arca carinata* and *Inoceramus concentricus* were not found by Mr. Downes below this bed.

No. 9 is the highest bed that contains concretions suitable for whetstones, and is only a few inches thick.

No. 10 is described as a sandstone, divided vertically at intervals of one to three feet by joints which cut clean through hard chalcedonic fossils. Mr. Downes observes, "Bivalves in this bed have their valves nearly always separated, and species are completely mixed. There is some but not much indication of attrition, and some of the fossils are broken, while all lie flatly on planes of bedding. . . . . The prevailing fossil is *Cyprina cuneata; Exogyra conica* is also very common, and *Trigonia scabricola*, though less common, is mainly if not entirely, confined to this bed. . . I found in all 46 species

in this bed, many of which range downwards into lower beds, while very few of them have a higher range."

Bed 11 consists chiefly of fine sand, with thin lenticular layers of drifted shells at intervals, and each layer being often two inches thick; the fossils in these layers being always waterworn, and often broken. *Pectunculus sublævis* and *Trigonia affinis* (=*excentrica*) abound in this bed, and are not found below it. A few other fossils occur more rarely, such as *Trigonia læviuscula*, *Cardium hillanum*, *Venus sublævis* and *Arca carinata*. *Scalaria Fittoni* is the only Gasteropod mentioned as occurring in this bed.

Bed 12 is described as sand "with layers of cherty sandstone passing upwards into chert," by which it is probably meant that in the lower part there are lenticular layers of cherty sandstone, while in the upper part these are replaced by nodules of chalcedonic chert. Its characteristic fossil is *Pecten* (*Neithea*) *quadricostatus*, which is rarely found lower in the Blackdown series. Other fossils are scarce, but *Trigonia dædalea*, *Pectunculus sublævis*, *Ostrea frons*, *Exogyra conica*, and a few others were found by Mr. Downes. He measured 25 feet of this sand on Blackdown before it was covered by the downslip of the disintegrated Chert Beds, but as the base of the sands is below 800 feet, and the ground rises steeply to over 920 feet, it is probable that there is more of the sand with cherts *in situ* below the loose chert gravel.

Comparing the above account with the coast-sections near Sidmouth, it is in the first place evident that the greater number of the Blackdown fossils occur in a band or zone which commences about 30 feet above the base of the sands, just as they do on Peak Hill, and that this zone is about 25 feet thick at Blackdown. From Mr. Downes' observations also it appears that all the Cephalopoda and nearly all the Gasteropoda are confined to this zone, and most of them to the lower part of it. The upper sands, which are at least 50 feet thick, differ in having a fauna of Lamellibranchs only, and these often distributed in layers of separated and waterworn shells. The horizon of the hard nodular glauconitic sandstone which underlies the Chert Beds along the coast has not yet been distinguished at Blackdown.

2.—The Haldon Hills.

These hills are situate about 12 miles south-west of the main escarpment of the Selbornian near Sidmouth, and their northern end is only three or four miles from the border of the Dartmoor Granite. They form a range about seven miles in length, which is divided by a col or lower ridge into two parts, known as Great Haldon and Little Haldon. Both parts attain a height of 800 feet in places, and consist in their higher portions of Upper Greensand, capped by some thickness of coarse gravel, which is now believed to be of Tertiary age.

These are the most westerly outliers of the Cretaceous series in England, a fact which invests the Haldon Sands with special interest. Considering this, it is remarkable that no one has published any connected account of them. The fossils which they contain are chalcedonic like those of the Blackdown Sands, and their existence has been known for the greater part of the century, but they have nearly all been obtained from one sandpit, and none of the many collectors has described this section.

My colleague, Mr. C. Reid, who was engaged in the re-survey of the district in 1875, discovered a good section in a water channel on the northern side of Great Haldon, obtaining some fossils from a few feet above the actual base of the formation. But unfortunately neither the mapping nor the observations then made were ever published.

The only attempt to determine the true stratigraphical relation of the Haldon Sands to those of Blackdown was that made by the Rev. W. Downes in 1882. From an inspection of the sand-pit whence the fossils had been obtained, and from a study of the fossils themselves, he came to the conclusion that the lower part of the Blackdown series is not represented at Haldon, that the base of the Haldon Sands is about on the horizon of his Bed 10 at Blackdown, and that the layers in which the Haldon Corals and other fossils are found belong to a higher horizon thar anything visible on Blackdown.

Great Haldon.—I visited Great Haldon in 1896, examining all the sections that were then accessible, and the following account is drawn up from my own notes except where otherwise mentioned. It will be seen in the sequel how far I am able to agree with Mr. Downes.

The most complete section visible in 1896 was that discovered by Mr. Reid in 1875, in a goyle or rain-channel which descends through the wood south-west of Woodlands and north of the race-course. The middle part of the section is partly obscured by talus, but by combining the notes taken by Mr. Reid and myself the succession appears to be as follows:—

	Feet.
Gravel with flints, in potholes.	
9. Fine yellowish sand, enclosing large lumps of light-grey chert, some shelly, scattered irregularly, not in lines	6 to 10
8. Yellow and grey sand with several layers of small quartz pebbles and a thin seam of grey micaceous clay	20
7. Coarse pebbly sand with many shell-fragments	1
6. Fine grey glauconitic sand with siliceous concretions, passing down into fine sand with some broken shells	19
5. Firm grey glauconitic sandstone, forming a ledge in the watercourse	1
4. Laminated grey and brown sand with broken shells	$1\frac{1}{2}$
3. Fine yellowish-green glauconitic sand with some irregular sandstone lumps, passing into next	6
2. Greenish-grey glauconitic sand with lenticular layers of glauconitic sandstone containing chalcedonised fossils	5
1. Conglomerate of pebbles derived from the Permian breccia, and resting on an uneven surface	2
Red Permian breccia seen for 30 or 40 feet.	
About	65

On the west side of the old Exeter road, at the top of Telegraph Hill, about $5\frac{1}{2}$ miles from Exeter, there are two sand-pits. The upper one shows gravel overlying rather coarse yellowish sand; a hole dug in one place exposed about 10 feet of such sand, consisting of quartz with many scattered black grains, which prove to be tourmaline, and a little mica. A peculiarity of the tourmaline grains is that they are not angular, but much

rounded. About 6 feet down there is a layer of very coarse sand containing *Exogyra conica.* Large lumps of chert lay by the side of the hole, and the sand which contains these seems to be dug into occasionally, for in 1875 Mr. Reid saw the following section here:—

	Feet.
Unworn and fractured chalk flints in whitish loam	3
Granitic sand with grains of schorl -	10
Fine light brown sand - - -	3
Sand with large tabular masses of chert	2
	18

The surface of the ground by this pit is 760 feet above the sea, and the top of the sand in the lower pit is about 725 feet, so that there may be 16 or 17 feet of unseen beds between the two sections. This space would correspond to that occupied by the sand, with large masses of clear chert, seen in the gully section and elsewhere.

The section seen in the lower pit in 1896 was as follows:—

	Feet
Peaty soil, with flints and cherts	2
Fine yellowish-grey sand - - - - - - -	3
Coarse pebbly sand, with many broken shells, chiefly *Exogyra conica* - - - - - -	2
Laminated green and yellow sand, with soft siliceous concretions in the upper part, and a layer of hard grey cherts at the base - - - - -	2
Bright green sand, with rubbly concretions - -	4
Greenish sand with two layers of small quartz pebbles and broken shells ("the pebble beds") - - -	4
Grey chert in a discontinuous layer.	
Grey glauconitic sand, with yellow streaks -	3
Firm grey speckled glauconitic sandstone - -	1
Ferruginous shelly and pebbly bed -	$1\frac{1}{2}$
Grey and yellow sand, with irregular rubbly concretions of sandstone containing sponge-spicules, seen for	6
	$28\frac{1}{2}$

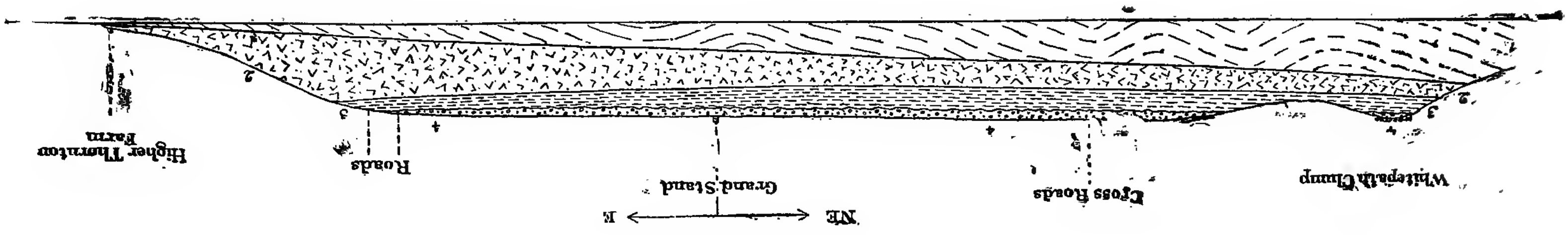
In 1875 the actual base of the greensand seems to have been exposed in this pit, for Mr. Reid records 11 feet of the sand with rubbly concretions, underlain by the following strata:—

	Feet.
Bedded glauconitic sandstone, with chalcedonic fossils -	1
Conglomerate of pebbles (1 to 3 inches in diameter), derived from the Permian breccia and occasional broken shells - - - - - - -	$1\frac{2}{3}$
Permian red rock (seen below).	

The total thickness of Upper Greensand proved here, therefore, amounts to about 34 feet, and if there are 32 feet above it we get 66 feet for the succession up to the base of the gravel; but as the ground rises southwards, higher beds may come in below the slippage of the gravel.

I was assured by the proprietor of the pit that the bed in

FIG. 66.—*Section across the northern part of Great Haldon.*



4. Grave with flints, &c. (Eocene
3. Upper Greensand.
2. Permian breccia and sandstone.
1. Culm-measures, &c.

** Base line 200 feet above Ordnance datum.

Horizontal Scale two miles to an inch, Vertical Scale 1,200 feet to an inch.

which most fossils had been found was the lower of the two in the middle of the section; a freshly-cut face showed this bed to be about a foot thick, of a brownish-grey colour; at intervals there occur in it lumps of the shelly sand agglutinated by silica, and also lumps of chalcedonised sand coloured red, brown and yellow. This I recognised as the "jasper," known to be associated with the Haldon fossils, and sold by dealers.

It is probable, however, that the bed which occurs 4 feet lower, and is 1½ feet thick, often develops similar characters, for Mr. Downes mentions the three shelly bands and says, "The two higher bands are thin and insignificant, but the third or lowest is about 1½ feet thick, a hard jaspideous mass full of fossil fragments. I detected in it *Ostrea* and *Exogyra* in abundance, *Trigonia Vicaryana* (Lycett), and *Vermicularia*, but no corals." He also says that "tons of the material might have to be removed before a nest of corals or Polyzoa would be found; and for a chance comer to find even a single specimen would be a fortunate circumstance.

It will be seen, therefore, that the idea of there being a bed of pebbles and fossils "above the Greensand at Haldon," as stated by Lycett in his Monograph on the Trigoniæ, is a mistake.

Some of the chert-beds, which must be concealed between these two pit-sections, are visible at the head of Harcombe Goyle where the water issues from beneath the Exeter road, about three quarters of a mile south of Telegraph Hill. Below the gravel, near the shoot, the following beds were seen in 1896:—

	Feet.
Yellow and grey glauconitic sand, without cherts -	6
Yellow sand, with cherts, small in the upper part, large in the lower part, seen for - - - -	10

Some of the masses of chert here were 3 or 4 feet long, and more than a foot thick; some contained shells, and I found *Lima semisulcata* (common), *Pecten orbicularis*, *Exogyra conica*, *Neithea quinquecostata* and casts of *Trigonia*. The yellow colour of the sand is clearly due to the oxidation of the glauconite it contains.

Near the head of Cullum Goyle, by the side of the road to Exeter and 3 miles from Chudleigh, a slip in the bank showed the following section:—

	Feet.
Fine grey glauconitic sand, enclosing many lumps of cherty stone, not chalcedonic, but whitish inside and often striped	10
Yellow sand full of pebbles of quartz and lydianite as large as peas - - - - - - -	2
Yellow sugary sand, with large grains of glauconite, coarse at top, finer below, seen for - - - -	6
	18

Lower down the gully are layers of rotten glauconitic stone in striped green and grey glauconite sand, which is probably not far from the base.

A quarter of a mile west of Ashcombe church a small excavation again shows the basal sandstones, which are soft and friable, weathering into thin slabs with green, red, and purple grains, the latter colours resulting from the oxidation of the glauconite. Mr. Reid saw this section when it was less overgrown than now, and he found many fossils, among which the following were identified by Mr. Etheridge: *Aporrhais Parkinsoni*, *Exogyra conica*, *Cardium hillanum*, *Cyprina angulata*, *C. rostrata*, *C. cuneata*, *Tellina inæqualis*, and *Neithea 5-costata*.

LITTLE HALDON.—Mr. Downes mentioned the existence of a complete section through the sands at Smallacombe Goyle (Op. cit. pp 83 and 91), but did not give any particulars of it. This exposure is, I believe, one of the finest sections in the district; it is on the eastern side of Little Haldon, at the head of Smallacombe Goyle, where a quarry has been opened for obtaining sand and chert-stones. For the following description of the beds here visible I am indebted to Mr. H. J. Lowe of Torquay, who visited the locality in 1899.

Section at Smallacombe Goyle.

	Feet.
1. Surface soil and flint gravel, the flints of various sizes but none large - - - - - - - -	7 to 9
2. Sharp coarse yellow sand, containing large irregular masses of chert up to two feet in diameter and arranged in rude layers - - - - - - - - - about	30
3. Brownish sand without cherts, in alternating layers of fine and coarser grain. - - - - - - about	15
4. Rather coarse brownish-greensand, with large grains of glauconite, including some lenticular seams of white sand.	7
5. Denser and greener sand with lumps of cherty stone, current-bedded and with some layers of darker green owing to preponderance of the glauconite grains; this passes down into glauconitic sand with flattish lumps of glauconitic sandstone. Lowest part hidden by talus. About -	40
About	100

The masses of chert in the upper beds consist of light brown translucent chert, with a thick outer crust of whitish and porous stone. Many of them exhibit a banded or laminated structure; examined with a lens they are seen to be crowded with sponge-spicules, and a few scattered grains of glauconite are visible.

The position of the shell-beds and of the coral fauna is probably in the upper part of the division numbered 5 by Mr. Lowe, where the beds of sandstone contain shells of *Exogyra conica* and casts ot other fossils. There is much glauconite, and the brownish colour in parts of this and of the higher beds is due to the oxidation of this mineral. The basement was not visible, but probably lies very little below the floor of the quarry.

It will be noticed that the total thickness here (92 feet) is much greater than in the sections on the northen side of Great Haldon. Confirmation of this is found in the following

account of a well sunk many years ago on Little Haldon for Sir R. Newman, and recorded by De la Beche[1]:—

		Ft.	in.
Gravel,	Small flints - - - - - - -	4	0
Chert-beds 29 feet	Brown sand - - - - - - - -	10	0
	Flints (chert?) large enough for building purposes - - - -	8	0
	White sand, much prized for making stucco	11	0
Greensands, 58½ feet	Red sand - - - - - -	1	0
	Fine-grained dark-coloured sand -	14	0
	Green sand - - -	9	0
	Large flint (chert?) mixed with light-coloured sand - -	13	0
	Fine brown sand - - - -	15	0
	Red Sand - -	4	0
	Pipe-clay, very white - - -	1	0
	Rounded gravel, like brook or river gravel -	1	6
New Red Series, Red Rock	- - -	4	0
		95	6

Mr. H. B. Woodward remarks that several localities for Upper Greensand in the Bovey Valley, were recorded by Godwin-Austen, and were represented on the old edition of the Geological Survey Map.[2] None of these was he able positively to confirm during his re-survey of the ground in 1874–75,[3] while quite recently Mr. Clement Reid sees reasons for grouping these sands and gravels, and those on Haldon, with the Bovey Beds, which are now regarded as Eocene.[4]

We have now some data for a comparison of the Haldon and Blackdown Sands. In the first place, we may notice that evidence now exists which was denied to Mr. Downes, for though he seems to have seen the basement-beds in Smallacombe Goyle on Little Haldon, he did not succeed in finding any fossils in them. He does not describe these beds, but says he saw two distinct beds beneath that which he numbers 12, and which he correlates with his No. 12 at Blackdown; he therefore assumes that these two beds correspond with his 10 and 11 of Blackdown. This conclusion he believed to be supported both by positive and negative evidence.

As positive evidence he states that "some of Mr. Vicary's specimens exactly agree with Bed 10 of Blackdown both in the fossils and in their mode of occurrence," that "*Pecten quadricostatus* and *Trigonia dœdalea* occur down to the very base of the series at Haldon;" and that "in every instance in which the Haldon fauna agrees with that of Blackdown, Bed 10 seems to be the probable downward limit."

As negative evidence he points to the absence of *Siphonia pyriformis, Inoceramus sulcatus* and *Trigonia aliformis,* and to the rarity of *Ammonites* and of *Pectunculus umbonatus,* all these forms being characteristic of low horizons at Blackdown.

[1] Report on the Geology of Cornwall, Devon, &c., p. 247.
[2] Trans. Geol. Soc., 2nd Ser., Vol. vi., p. 452.
[3] Quart. Journ. Geol. Soc., Vol. xxxii., p. 230.
[4] *Ibid.*, vol. liv., p. 234.

It is certainly a fact that the fossils found by Mr. Reid tend to support Mr. Downes' conclusion; they are all of them species which occur in Bed 10 at Blackdown; some of them such as *Aporrhaïs Parkinsoni* and *Cyprina cuneata* are specially characteristic of that bed. I am therefore disposed to think Mr. Downes was right in his general statement, and that not only have the 30 feet of unfossiliferous sand thinned out between Sidmouth and Haldon but that some 20 feet of the Blackdown fossiliferous beds have also disappeared in the interval.

I also agree with Mr. Downes that a part of the Haldon series is higher than anything seen at Blackdown, but I do not think that any part of the series is newer than the Chert Beds of the Devon coast-sections, and I feel sure that the position of the schorlaceous sand is above, not below, the Chert Beds.

The sand with rubbly siliceous concretions does not appear to be anything like so thick as Mr. Downes supposed; instead of being 35 feet, it is not more than 11 feet. Further, as no fossils have been found in it in situ, its correlation with Bed 12 is very doubtful. Nor do I regard the lithological character of the pebbly beds, nor their coral fauna, as sufficient proof that this portion of the series is newer than anything at Blackdown. The distance from Blackdown and the probable proximity of a coast-line are facts quite sufficient to account for the pebbles, which are very small, and for the corals; while in other respects the fauna differs little from that of Beds 11 and 12 of Blackdown.

My view of the case may be expressed by saying that, if his method of numeration be adopted, the greensands below the Chert-beds of Haldon correspond with 10, 11, 12 of Blackdown, that the Chert Beds should be numbered 13 and the overlying sand 14, these two only being higher than anything seen at Blackdown, and corresponding to a part or the whole of the Chert Beds seen in the coast sections.

The following is a general list of Fossils from the Haldon Sands, below the Chert Beds. It is based on the list given by Mr. Downes, with some additions from the Survey collections:—

Ammonites (fragments).
Actæon affinis, *Sow.*
Avellana incrassata, *Sow.*
Aporrhais Parkinsoni, *Sow.*
Dentalium medium, *Sow.*
Natica Genti, *Sow.*
Phasianella sp.
Turritella granulata, *Sow.*
Turbo sp.
Arca carinata, *Sow.*
„ rotundata, *Sow.*
Astarte formosa, *Sow.*
„ obovata, *Sow.*
Avicula anomala, *Sow.*
Cardium hillanum, *Sow.*
„ gentianum, *Sow.*
Corbula elegans, *Sow.*
Cucullæa glabra (=fibrosa) *Sow.*
Cyprina angulata, *Sow.*
„ cuneata, *Sow.*
Cyprina rostrata, *Sow.*
Cytherea caperata, *Sow.*
„ lineolata, *Sow.*
„ plana, *Sow.*
Exogyra conica, *Sow.*
„ plicata, *Sow.*
Gervillia anceps, *Sow.*
„ rostrata, *Sow.*
Lima rapa (?) *d'Orb.*
Lucina orbicularis, *Sow.*
Mactra angulata, *Sow.*
Mytilus tridens, *Sow.*
Nucula obtusa, *Sow.*
Ostrea frons, *Park.*
„ sp.
Opis Galliennei, *d'Orb.*
Pecten curvatus, *Gein.* (=divaricatus).
Pecten Milleri, *Sow.*
„ sp.

Pecten (Neithea) 4-costatus *Sow.*
„ „ 5-costatus *Sow.*
Pectunculus umbonatus, *Sow.*
„ sublævis, *Sow.*
Spondylus striatus, *Sow.*
Tellina inæqualis, *Sow.*
„ striatula, *Sow.*
Thetis gigantea, *Sow.*
Trigonia affinis, *Miller.*
„ dædalea, *Park.*
„ scabricola, *Lyc.*
Trigonia spectabilis, *Lyc.*
„ vicaryana, *Lyc.*
„ sp.
Venus sublævis, *Sow.*
Rhynchonella dimidiata, *Sow.*
(Polyzoa, many, unnamed).
Serpula plexus, *Sow.*
„ concava, *Sow.*
Discoidea subuculus, *Leske.*
Parkeria sphærica, *Carter.*
Elasmostoma normanianum, *d'Orb.*

Vertical Distribution of Fossils at Haldon, so far as at present known.

—	Basement Beds.	Middle Beds.	Chert Beds.
Ammonites sp.	x	–	–
Aporrhais Parkinsoni, *Sow.*	x	–	–
Turritella granulata, *Sow.*	x	–	
		–	–
Arca rotundata, *Sow.*	–	x	–
Cardium hillanum, *Sow.*	x	x	–
„ gentianum (=probosci-	x	–	–
deum) *Sow.*	–	–	–
Cyprina angulata, *Sow.*	x	–	
„ cuneata, *Sow.*	x	x	
„ rostrata, *Sow.*	x	–	–
Cytherea plana, *Sow.*	x	x	–
Exogyra conica, *Sow.*	x	x	–
Gervillia anceps, *Sow.*	–	x	x
Lima semisulcata, *Nils.*	–	–	–
„ rapa (?), *d'Orb.*	–	x	x
Modiola reversa, *Sow.*	–	–	–
Opis Galliennei (?), *d'Orb.*	–	x	x
Ostrea frons, *Park.*	x	–	
Pecten curvatus, *Gein.*	x	–	–
„ orbicularis, *Sow.*	–	–	–
„ (Neithea) 4-costatus, *Sow.*	–	x	x
„ „ 5-costatus, *Sow.*	x	–	–
Pectunculus, umbonatus, *Sow.*	–	x	x
Spondylus striatus, *Sow.*	–	x	–
Tellina inæqualis, *Sow.*	x	–	–
Trigonia affinis, *Sow.*	–	x	–
„ dædalea, *Park*	x	x	–
„ scabricola, *Lyc.*	x	–	–
„ vicaryana, *Lyc.*	–	x	–
Discoidea subuculus, *Klein*	–	x (?)	–
Orbitolina concava *Lam.*	x	–	x
Corals (see subsequent list)	–	x	x
Polyzoa	–	x	–
Elasmostoma normanianum, *d'Orb.*	–	x	–

CHAPTER XVI.

GAULT AND UPPER GREENSAND (SELBORNIAN) IN SOUTH WILTSHIRE.

Having now given an account of the Selbornian deposits in the southern counties, we take up the description of the stage as developed in Wiltshire.

The outcrop of the Selbornian in this county is very irregular, owing to the flexures which run through it and give rise to the Vales of Wardour, Warminster and Pewsey. (See Map, p. 248). In these areas the sandy portion of the formation attains a considerable thickness and occupies a larger area than in any other part of England except Devonshire. Consequently in describing the Gault and Greensand of Wiltshire it will be convenient to deal separately with the areas above mentioned.

1. The Vale of Wardour.

The general structure of the Vale of Wardour has been explained on page 5, and is illustrated by the transverse section Fig 67.

Along its northern side the dip of the beds is everywhere steep, while along the southern side they are so slightly inclined as to appear horizontal; as a consequence the basset surface of the Gault and Upper Greensand along the northern border is often very narrow, while on the southern side this tract is much wider.

The general succession is not unlike that in the Isle of Wight and the total thickness is about the same as in the south of that island.

The Gault of this district, like that farther south, corresponds to the Lower Gault only. It passes up into a kind of impure malmstone, or fine micaceous sandstone containing a variable quantity of colloid silica, and this in turn passes up into soft sands.

The higher members of the series consist first of a massive glauconitic and calcareous sandstone formerly much quarried as a building-stone; this is succeeded by soft grey silty sands with lenticular layers of chert, and finally by gritty green sand.

Dr. Fitton gave a good general account of the Gault and Greensand in the Vale of Wardour in 1836,[1] but his estimate of the thicknesses was rather too little, for he makes the Gault only 75 feet and the Greensand about 100 feet, whereas our estimates based on the six-inch maps give from 90 to 100 feet for the Gault and about 150 feet for the Greensand, making a total of not less than 240 feet.

[1] Trans. Geol. Soc. Ser. 2, Vol. iv, p. 246.

Lower Gault.

The base of the Gault throughout the Vale of Wardour is marked by a thin layer of small pebbles, mostly of quartz and lydianite (or black chert) and about the size of peas or beans but some larger. Above this is a bed or beds of brown ferruginous sandstone, which is thin at the western end of the Vale but thickens towards the east. A well sunk at Dinton, north-east of the church, in 1890, passed through the lower part of the Gault into the Lower Greensand, and the following is a summary of the beds traversed[1]:—

		Ft.	in.
	Surface soil	1	6
Gault clays	Yellow and grey clays	5	0
	Hard ferruginous stone	0	8
	Brown clays with a layer of brown stone	15	0
	Dark grey clay with selenite, some fossils and a few small phosphate nodules	5	0
Basement Beds	Hard grey ferruginous sandy rock, fossils	5	8
	Reddish-brown sandstone with scattered pebbles, fossils and fragments of wood	2	6
	Layer of small pebbles	0	6
Lower Greensand	Brown and grey sands and stone beds	26	8
	Grey and black clays	7	0
		69	6

It will be noticed that the basement-beds are here 8 ft. 8 inches thick, and it might have been expected that they would yield the fauna of the zone of *Ammonites mammillatus*, but this does not seem to be the case.

The following fossils were obtained from the brown sandstone by the Rev. W. R. Andrews and identified by Mr. Sharman and myself:—

Ammonites sp. (? Deshayesi or denarius).
Natica sp. (? Genti).
Arca (Cucullæa) carinata.
Cytherea sp. (? plana, young).
Inoceramus concentricus.
„ sp. (large).
Lima sp.
Modiola sp.
Mytilus sp.
Ostrea vesicularis.
Pecten orbicularis.
Pinna sp. (several).
Pleuromya mandibula
Terebratula biplicata.
Holaster lævis.

From the overlying hard grey rock were obtained:—

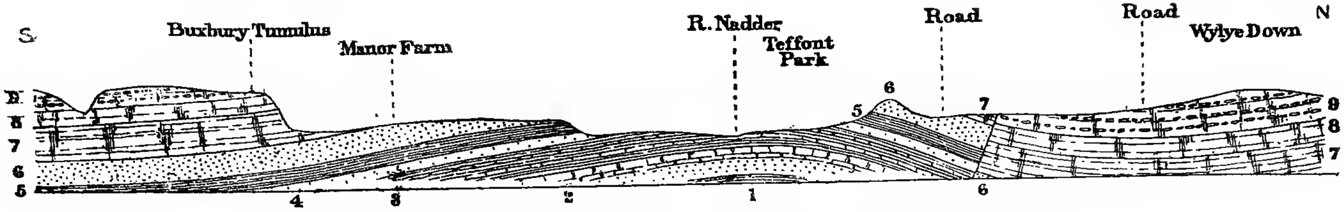
Ammonites (Hoplites) sp.
Turbo sp. (not *munitus*).
Inoceramus sp. (large).
Cucullæa glabra.
„ sp.
Arca Raulini ?
Cardium raulinianum ? (not *sub-hillanum*).
Pleuromya plicata ?
Cyprina angulata.

In the clay above Mr. Andrews found the following:—

Am. interruptus.
Trigonia Fittoni.
Pleuromya mandibula.
Pecten orbicularis.
Inoceramus sp.
Pinna sp.

[1] See Geol. Mag., Dec. 3, Vol. viii., p. 292.

FIG. 67. *Section across the Vale of Wardour.*[1]



Horizontal Scale, one mile to an inch. Vertical Scale, 1,200 feet to an inch.

9. Upper Chalk.
8. Middle Chalk, 100 feet.
7. Lower Chalk, 220 feet.
6. Upper Greensand, 160 feet.
5. Gault, 90 feet.
4. Lower Greensand and Wealden, 60 feet.
3. Purbeck Beds, 170 feet.
2. Portland Beds.
1. Kimeridge Clay.

[1] See also Memoir on Jurassic Rocks of Britain, Vol. v. p. 205.

The only excavation in the Gault along the north side of the Vale is that of a brickyard at Ridge, west of Chilmark. Here about 40 feet of dark grey micaceous silty clay is seen containing a nearly continuous layer of dark grey argillaceous and calcareous mudstone or silty sandstone. Small ovoid dark-coloured septarian stones are scattered through the clay, and one of these was analysed for us by Prof. J. B. Harrison, F.G.S., of Demerara, the result showing the presence of much phosphate of lime (51·6 per cent.), carbonate of iron (6 per cent.), and carbonate of lime (19·38 per cent.), the latter probably being chiefly from the calcite-veins which traversed the nodule. These phosphatic nodules are common in the Gault throughout Wiltshire and the northern part of Dorset; they run from 3 to 5 inches in length, and are often 2 inches in diameter.

The bedding as shown by the layer of sandstone masses is between 5° and 6° to the north. The difference of level between the base and top of the Gault is about 50 feet, the width of basset surface is about 500 feet, and on a level with a dip of 5° this would bring in a thickness of 43½ feet, so that there is certainly more than 90 feet assignable to the Gault.

Fitton records the following fossils from this exposure:—

Ammonites Beudanti	Rostellaria carinata.
„ dentatus [interruptus]	Pectunculus umbonatus.
„ tuberculatus.	Cytherea parva?
„ selliguinus (?)	Lima elongata (=parallela d'Orb).
„ varicosus [? an error]	Terebratula sp.
Avellana inflata.	Astacus [? Hoploparia].
Dentalum decussatum.	

The Rev. W. R. Andrews has himself obtained *Ammonites interruptus*, *Am. splendens*, *Inoceramus sulcatus* and a large species of *Cucullæa*, probably *glabra*.

Upper Greensand.

Zone of Ammonites rostratus.

There are many exposures of the beds composing this zone on both sides of the Vale of Wardour. It forms the mass of what is called the Upper Greensand, and the general succession is as follows:—

		Ft.	in.
Glauconitic sandstone (zone of Pecten asper)			
Zone of *Ammonites rostratus*	Soft greenish-grey sand with hard irregular calciferous concretions (no chert)	9	0
	Fine greenish-grey sand, often laminated and current-bedded - about	30	0
	Buff coloured sands, becoming micaceous below and passing into soft micaceous sandstone	50	0
	Impure sandy malmstone, from 15 to	30	0
Gault (grey sandy micaceous marl)			

The thicknesses given are approximate only, and the total probably varies between 105 and 120 feet.

On the south side of the Vale there is a good section of the malmstone in a deep fosse-way by Sutton Mandeville Church. The beds dip at about 12° to the south and the top is not seen, but there seems to be a thickness of about 30 feet; most of it is a light-grey stone of small specific gravity, so that it feels light in in the hand, but some of the beds are heavier and more argillaceous with spots and streaks of dark grey marl. The stone weathers into beds of 6 to 12 inches thickness.

Along the north side of the Vale the malmstone and the overlying micaceous sandstone can be seen behind the stables of Fonthill House and in the lane leading to Fonthill Gifford, where the sandstone contains *Serpula (Verm.) concava* and *Exogyra columba*. The sandstone is also well exposed by Knap Farm near Ridge, where it has the character of a true gaize like that of Devizes (*see* pp. 55 and 251); here also it contains *Serpula concava* and impressions of bivalve Mollusca. It is also visible in the lane north of Dinton.

The best sections through the sands which form the higher part of the zone are:—

The large sand-pit below Knoyle Hill.
The lanes near Ridge.
A sand pit in Upper Holt, north-west of Teffont.
The lane north of Dinton.
Large sand-pits by the road north-west of Dinton Manor Farm.
The railway cutting near Baverstock.
The lane down the north side of Fir Hill, near Fovant.

Zone of Pecten asper and Cardiaster fossarius.

This sub-division is well developed in the Vale of Wardour, and consists of the following beds:—

Green sand or sandstone, from 6 to 10 feet.
Chert Beds, from 20 to 30 feet.
Glauconitic sandstone, from 9 to 16 feet.

the average thickness being probably about 45 feet.

The glauconitic sandstone is exposed in many of the lanes and roadways on both sides of the Vale, and its thickness increases from 9 feet on the western side to 14 or 16 feet towards the eastern end. In the middle or upper part of it there is a layer about 12 inches thick which consists almost entirely of *Ostrea vesiculosa* shells, and where the rock has been decomposed into soft sand and sand-rock this bed of Oyster shells becomes a very conspicuous feature.

The stone has been quarried in many places for building-material and was formerly in much request. Dr. Fitton says it was called "Greenstone" at Fovant, and adds "it is valuable from its not being affected by frost. It can therefore be dug at any season, and stands well in water as in the foundations of bridges, and in exposed situations as in copings &c."[1]

[1] Trans. Geol. Soc. Ser. 2, vol. iv., p. 246.

The best section on the south side of the Vale is that of the old quarry at Fovant near the Pembroke Arms. Dr. Fitton gave the succession here, and his account differs little from the following, which was taken in 1890:—

	Feet
Soil and Rubble - - -	3
Fine grey silty sand, with layers of chert and white porous siliceous stone - - -	8
Soft grey sand, with two layers of greenish calcareous stone	4
Soft grey sand, with nodular lumps of calcareous grit, passing down into tough greenish sandstone with irregular lumps of hard grit - - - - -	6
Firm greenish sandstone, standing with a vertical face and weathering yellowish brown -	10
	31

The only fossils seen in the sandstone were *Pecten orbicularis* and *Ostrea vesiculosa*, but Dr. Fitton also mentions Sharks' teeth. The beds are nearly horizontal, and form part of a plateau, which has a gentle slope to the southward. The stone is rather coarse in grain, the glauconite grains being large, dark green, and conspicuous.

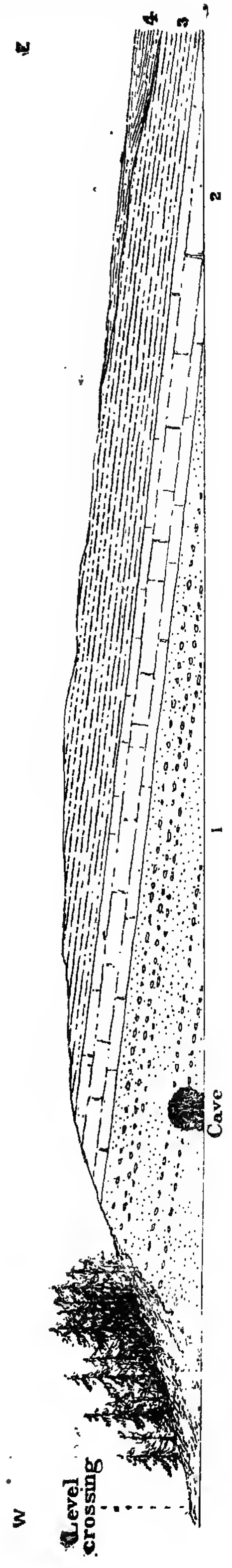
The highest beds of the Greensand are well exposed near Baverstock. In the wood about half a mile east of the church is a small sand-pit which shows marly glauconitic sand (about 3 feet), passing down into sharp bright green sand (about 8 feet). This must be just below the "Chloritic Marl." In the railway-cutting to the south-eastward lower beds are seen with a dip of about 10° to the north-east, by which the following succession is brought in (see Fig. 68):—

	Feet.
Fine grey sand with layers of black chert and white porous stone - - - - - - -	6
Fine grey sand, with irregular layers of porous stone, and doggers of hard calcareous stone - - -	8
Light greenish grey marly sand, with a layer of grey calcareous stone at the base - - - - - -	$1\frac{1}{2}$
Firm greenish sandstone, with vertical joints. *Ostrea vesiculosa* abundant about the middle - - - - - -	13
Soft grey sands with lenticular layers of hard siliceous stone in the upper part, seen for - - - - - - -	25
About	54

The junction of the Chalk and Greensand can be seen about a mile east of East Knoyle in a narrow roadway leading up into what are called the Bull Pits. The section here is as follows:—

		Feet
Chalk Marl and Chloritic Marl - - - - - - -		7
Hard glauconitic sandstone with a few phosphates - - -		2
Zone of Pecten asper	Hard coarse glauconitic sandstone, with large quartz grains, *P. asper* - -	1
	Soft yellowish grey sand - - - -	3
	Greyish sand with lenticular layers of chert and cherty stone, from - - -	25 to 30
	Firm glauconitic calcareous sandstone -	12
Soft grey and buff sands below.		

FIG. 68. *Section of railway-cutting at Baverstock, Wiltshire.*



Length of cutting about a quarter of a mile.

1. Soft Sands. 2. Sandstone. 3. Chert Beds. 4. Soil.

One of the best sections is in the quarries at Upton, two miles west of Hindon. Here the glauconitic sandstone has been quarried at the top of the hill for a distance of about 200 yards; it appears to be 9 or 10 feet thick, and it yielded the following fossils: *Pecten asper, P. Galliennei, P. orbicularis, Neithea quinquecostata,* and *Spondylus striatus.* At the north-west end of the quarry is a face showing about 20 feet of the Chert Beds dipping N.N.E. at 33°, and consisting of soft marly sand with many thick irregular layers of whitish siliceous stone (sponge rock, *see* p. 64) and some lenticular masses of black and brown chert near the top.

2. Stourton, Longleat and the Vale of Warminster.

The Gault, which is cut off on the south side of this fault at West Knoyle to the east of Mere, appears again on the north side of it near Penselwood, about four miles west of Mere. On the old Geological Survey Map the Gault was coloured as Kimeridge Clay from Penselwood to Bradley Mill, where the Greensand was supposed to overlap it on to Oxford Clay, but the writer found this to be a mistake; the Gault is really continuous, and can be traced through Longleat Park and thence round the Greensand Hills of Corsley and Chapmanslade. There are also two inlying tracts of Gault, one near Stourton and the other at Crockerton, near Warminster.

The malmstone comes in above the Gault, and is succeeded by a varied series of sands which form a high plateau by Stourton, Kilmington, and Maiden Bradley, having a steep western slope, but falling gently to the eastward toward the Chalk hills which divide the Vale of Wardour from that of Warminster.

The Warminster anticline has a much lower structural elevation than those of the Vales of Wardour and of Pewsey, and it does not form a long valley or hollow between high Chalk ridges as they do. It is really a prolongation of the Greensand plateau above mentioned, and it is only near Crockerton that the Greensand has been so far removed as to expose the Gault over a small space in the valley of the river Wily.

Passing round Cley Hill, west of Warminster, the outcrop of the Greensand trends north-westward to Westbury, and thence takes a still more westerly direction toward the mouth of the Vale of Pewsey.

Through the district above described the Gault maintains a thickness of from 70 to 90 feet, but that of the Greensand varies and diminishes considerably toward Westbury, where some of the beds thin out and disappear entirely, so that whereas between Maiden Bradley and Warminster the thickness of the Greensand is from 150 to 160 feet, near Westbury it is not more than 80 or 90. Further east, however, by Cheverell and Lavington it thickens again, and is probably about 140 feet. The following tabular view shows this variation and the composition of the formation in three different localities, A being the

district near Maiden Bradley, Horningsham, Crockerton and Longbridge Deverill, B that of Dilton and Westbury, C that of Market Lavington.

	— — —	A	B	C
		Feet.	*Feet.*	*Feet.*
3.	Green sand often fossiliferous, and containing nodules and layers of calcareous stone - - - - -	4—10	15—20	30
	"Chert Beds"—fine greyish spicular sands, with layers of chert and siliceous stone - -	25	10–0	0
	Green sands with layers of glauconitic limestone or greensand-rock	7—12	0	30
2.	Green, grey, and buff sands, more or less micaceous, with *Exogyra conica*, and passing down into soft micaceous sandstone containing large "burr-stones" - -	100	60	75
	Light grey malmstone - -	20	10	15
1.	Dark grey sandy micaceous clay	20	70	80
	Grey micaceous and glauconitic clay	60		
	About	240	160	230

Tho beds bracketed as 1 form the Gault of Wiltshire—*i.e.*, the Lower Gault, including the zones of *Am. interruptus* and *Am. lautus*, that of *Am. mammillatus* not having been proved to exist.

The higher beds constitute the Upper Greensand. Those in bracket 2 are the Devizes Beds (zone of *Am. rostratus*), which, however, are very poor in fossils in this part of Wiltshire. Those in bracket 3 are the Warminster Beds with *Pecten asper* and *Cardiaster fossarius*, both of which are generally to be found.

Although the Chert Beds are represented as thinning out, and the sands above and below as thickening, we are inclined to believe that what really takes place is a lateral change from spiculiferous sand, with its accompaniment of cherts, to a coarser glauconitic sand with calcareous rock, so that the Chert Beds of Warminster and Deverill merely replace a portion of the glauconitic sands of Lavington and Devizes,

Lower Gault.

There are two brickyards in the Gault, one in the valley of the Redford Water, about a mile north of Longleat House, the other at Flintford, on the main road from Warminster to Frome..

At the former locality the clay is dug for about 12 feet, and consists of dark grey sandy micaceous clay, with a few scattered glauconitic grains and nests of such grains here and there. Phosphatic septaria occur like those of Ridge and North Dorset (see pp. 230 and 158), and there are also a few smaller phosphatic

nodules. Fragments of *Ammonites interruptus* and *Am. Beudanti* were found.

At Flintford there is a more extensive excavation and a more interesting succession; this as seen in 1889 was as follows:—

	Feet.
Yellow loamy clay, passing down into lilac-grey silty micaceous clay - - - - -	8
Layer of rubbly ferruginous marl	$0\frac{3}{4}$
Dark grey micaceous clay - -	3
Soft bright red sandy clay - - -	1
Dark grey clay, tough and homogeneous, dug for	6
About -	19

These layers are persistent all round the pit, but at the north-east end the upper part of the clay is loose and mixed with glauconite grains like that near Longleat. Septarian nodules are abundant, especially near the ferruginous band, and some of them are so brittle that they break up on being tapped with a hammer. The only fossil seen was a bit of *Am. Beudanti.*

A different section, in what is probably a rather higher part of the clay, is seen in the brickyard at Crockerton, south-west of Warminster. where the Gault is brought up by a low anticlinal flexure. The clay here is dark grey throughout to a depth of over 20 feet, and it contains rather large phosphatic septarian concretions, some being as thick as a man's arm. At a depth of about 25 feet there is a course of large lenticular masses or doggers of hard dark-grey sandy stone; these are from 6 to 8 inches thick, and are internally of a greenish grey, as if containing glauconite. Many fossils have been found here, and the following is a list of the species which have been obtained from this locality at various times:—

Ammonites benettianus.
" Beudanti.
" denarius.
" lautus.
" interruptus.
" splendens.
Actæon affinis.
Aporrhais carinata.
" marginata.
Natica rotundata.
" Genti.
Arca carinata.
Cardita dupiniana
" tenuicosta.
Corbis gaultina.
Nucula pectinata.
Pecten orbicularis.
Pectunculus umbonatus.

At Westbury the Eden Vale Brickyard showed the following section in 1889:—

	Feet.
Top earth and soil - - - - - - - - - -	4
Sandy micaceous clay, yellowish near surface, lilac-grey below, with black septarian phosphatic concretions	6
Layer of brown ferruginous rubbly marlstone with iron pyrites (a soft ironstone) - - - -	1
Dark lilac-grey clay, dug for - - - - - - -	8
	19

Ammonites interruptus is not uncommon here, but I did not see any other fossils.

Upper Greensand (Malmstone and Micaceous Sands).

Zone of Ammonites rostratus.

The malmstone has been traced continuously throughout this part of Wiltshire; its base is marked by the issue of strong springs at intervals, and in these spring-heads the stone can sometimes be seen, as in that west of White Street, Horningsham and in the spring-heads north-east of Westbury.

The thickness of what may correctly be called malmstone seems to vary from 15 to 25 feet, but there is no complete section of it, and it passes up into the soft micaceous sandstone or Gaize, which is really only a more sandy form of the same kind of rock. One of the best sections is in a pit at Water Farm, north-east of Corsley; here about 8 feet of light grey compact stone are seen, one course about a foot thick being hard; in the lane above softer stone is seen passing up into loose micaceous sand.

In the inlier near Crockerton these beds can be seen in several places above the Gault. Thus in the road near the brickyard pale grey silty marl is seen overlain by rubbly malmstone and yellowish grey sand; but the succession of malmstone, sandstone and sand is better seen in the bank and road-cutting above Sutton Veny Mill.

The highest beds of this zone are exposed in a sand-pit by the school-house in Cannamore Lane, west of Warminster, which in 1889 showed the following face:—

	Feet.
Dark soil	2
Soft greenish, fine-grained and laminated sand	16
Layer of decomposed ferruginous concretions.	
Light-grey micaceous sand, seen for	6
	24

In the road-cutting south of the church at Dilton Marsh, near Westbury, malmstone (weathered and yellowish) is seen at the bottom overlain by buff-coloured sand, which is coherent enough to stand in a face 15 to 18 feet high. The same sand is seen in the railway-cutting to the south-east, and it contains large boulder-like matter, or "doggers," of hard calcareous stone, which are locally called "burr-stones." They seem to be masses of the sand compacted by a cement of crystalline calcite, and they have been used in the construction of the bridges on the railway-line near Dilton.

At Westbury, above Bitham springs, which mark the outcrop of the malmstone, and east of Prospect Square, is a large sand pit showing about 20 feet of soft fine greenish-grey sand, weathering yellow, with a course of large "burr-stones," some of which are 2½ feet long by 1½ deep; internally these are very hard and compact, of a dark grey colour, and they contain *Serpula* (*Vermic.*) *concava*, *Exogyra conica*, *Pecten orbicularis*, and *Pecten* (*Neithea*) *quinquecostata*. At this point the total thickness of malmstone and sand to the base of the Chalk seems to be less than 80 feet.

Upper Greensand (Warminster Beds).

Zone of Cardiaster fossarius.

The actual succession of the beds which form this part of the series near Maiden Bradley has been given on page 235, and a good section of the uppermost beds, and of their junction with the Chloritic Marl is exposed in the quarry north-west of the church at Maiden Bradley. The following particulars of this section were obtained by Mr. J. Scanes, the Master of Bradley National School, and their accuracy has been confirmed by Mr. Hill, who visited the quarry in 1897:—

		Ft.	in.
	Surface soil	1	6
3.	Chloritic Marl, with scattered phosphatic nodules and fossils; marly above, sandy below	2	0
	Brownish glauconitic sand with a layer of brown fossils and phosphatic concretions at the base	0	6
2.	Layer of calcareous concretions, brown outside, whitish within, packed in glauconitic sand	1	0
	Glauconitic sand, with some calcareous concretions	2	9
1.	Fine greyish white spiculiferous sand with lumps of grey chert	3	6
	Fine grey glauconitic sand with broken *Pecten 4-costatus* and *Cardiaster fossarius*	2	0
	Large blocks of cherty stone, nearly continuous	1	6
	Fine grey glauconitic sand	1	0
	Hard granular sponge rock	1	9
	Light grey spiculiferous sand seen below		
		About 18 feet.	

The beds bracketed as 1 belong to the Chert Bed group. The overlying glauconitic sand appears to be the equivalent of the bed which, near Shute and Rye Hill, has yielded the fauna known as that of the Warminster Greensand. The succeeding bed of closely packed concretions is a remarkable layer; the lumps of stone are locally called "cornstones," they have a brownish crust, and do not seem to be exactly *in situ*, but have the appearance of being the remnants of a bed from which the sand has been riddled or washed away. They differ, however, from the concretions in the sand below, being of a finer grain.

We consider the "cornstones" as the highest bed of the Greensand in this section, and the succeeding beds will be described under the head of Lower Chalk.

Mr. Hill and Mr. Scanes have found a certain number of fossils in the sand below the "cornstone" bed, and has sent them to me for identification. The following is a list:—

Ammonites curvatus.	Exogyra conica.
„ Mantelli.	Ostrea vesicularis.
„ varians.	Pecten asper.
„ „ var Coupei.	Inoceramus sp.
Nautilus deslongchampsianus.	Terebratula biplicata.
„ lævigatus.	Rhynchonella grasiana.
Turrilites sp.	Cardiaster fossarius.
Dentalium rotomagense (?).	Discoidea subuculus.
Arca mailleana.	Serpula sp.
Lima semisulcata.	Tremacystia Orbignyi.

The Chert-beds are quarried at several places near Maiden Bradley, and they have been more extensively worked near Stourton and Penselwood to the south-west. Mr. H. B. Woodward[1] estimates their thickness at the latter place as between 20 and 30 feet. They include layers of hard chert and of porous siliceous stone, and the latter was formerly extracted for building-material and for the manufacture of whetstones for sharpening scythes, and were known as "pen-stones." The pits from which they were dug still remain as conical depressions or holes, and under the name of "Pen-pits" were supposed to be the remains of early British habitations.[2]

Dr. G. J. Hinde remarks that sponge-spicules are very abundant in these chert beds, and that "the sponge beds of this locality are distinguished by the absence of calcite and by the small proportion of glauconite and mica in them. . . . In addition to the chert and porous siliceous rock, some of the sponge-beds consist of a hard whitish massive rock of a granular character, filled with spicules of a white porcellanic tint. The rock appears to be entirely siliceous; the silica is partly chalcedonic and partly amorphous, and in the globular form."[3]

The above description will apply also to the Chert-beds at and near Maiden Bradley, the hard granular rock at the bottom of the quarry above described being of the kind mentioned by Dr. Hinde.

The fossils which are generally known as those of the Warminster Greensand were not obtained at or very near Warminster, but most of them came from a sand pit in a field on Shute Farm, which is three miles south-west of that town, and about the same distance E.N.E. from Maiden Bradley. The site of this old pit was pointed out to me in 1889, and I had a trench dug down the slope of the depression which had been the pit; this trench proved the existence of Chloritic Marl for about three feet, the upper two feet being a hard glauconitic and gritty chalk with many phosphatic nodules passing down into softer sandy marl, with fewer phosphates; digging a hole below this a loose green sand was found, which contained no phosphatic nodules, but yielded many of the small Brachiopods and Echinoderms belonging to the "Warminster" fauna.[4]

It was evident, therefore, that at this spot there exists a fossiliferous green sand overlain by beds having the usual characters of the Chloritic Marl or zone of *Stauronema Carteri*. In other parts of the field, which lies to the south of Shute Farm, fossils like those of the green sand in the pit can be picked up on the surface, and I purchased a handful from one of the farm labourers which had been so picked up after the field had been ploughed.

[1] Geology of East Somerset. Mem. Geol. Survey, p. 138.

[2] See Rev. H. H. Winwood, Proc. Somerset Arch. and Nat. Hist. Soc. vol. xv., and H. B. Woodward, Midland Naturalist, 1883.

[3] On Beds of Sponge Remains in the Lower and Upper Greensand of the South of England. Phil. Trans. Roy. Soc., 1885, p. 420.

[4] For details respecting the Warminster Greensand and its Fossils, see a paper in Geol. Mag., Dec. iv., vol. iii., p. 261, 1896.

At Rye Hill Farm (Ray Hill on the old Ordnance map) which is half-a-mile south-east of Shute Farm, the junction of this fossiliferous sand with the Chloritic Marl is exposed in two small pits dug in the lane which runs on the southern side of the farm. The beds seen here in 1889 were as follows:—

	Feet.
Sandy marl and calcareous sand, with a few scattered brownish phosphates - - - - about	3
Passing into sharp greenish-grey sand, slightly calcareous, with many fossils - - about	$2\frac{1}{2}$
Green sand, including scattered lumps of hard white calcareous stone ("Cornstones")	1

There is a complete passage downwards from the Chloritic Marl, but there are no phosphates in the fossiliferous portion of grey sand, which is loose and easily dug, while the glauconitic marl above is hard and set like mortar. The grey sand consists largely of small angular grains of quartz, varying much in sizes, and mingled with grains of glauconite. *Discoidea subucula* is not so abundant here, though common, but *Rhynchonella grasiana* abounds; *Ammonites varians* is not uncommon, some of them being broken casts in a hard yellowish calcareous paste.

The layer of hard calcareous nodules does not form a separate bed; the nodules are simply scattered through a thickness of sand which varies from 9 to 14 inches in depth; they are of all shapes and sizes, from that of a walnut to a good-sized turnip, some lie obliquely in the sand, and some have their longer axis nearly vertical; they are rather decomposed on the outside, and small oysters are attached to some of them. In size, shape, and internal structure they are just like the "cornstones" of Maiden Bradley, but they are not phosphatised, and seem here very slightly displaced from their original positions. The sand in which the lowest of them are embedded is of a rather darker green than that above, but otherwise similar.

South-east of these pits green sand is seen in the bank, and may be 6 or 7 feet thick, a floor of chert crossing the lane below them.

Many collections contain fossils in brown and black phosphate labelled as coming from "Warminster Greensand," and the inclusion of these in previously published lists has led to mistakes in the correlation of other beds with this Rye Hill and Shute Farm Sand. There are no dark phosphates in these sands, and those so labelled must have come from the Chloritic marl which overlies it, and which contains many fossils (chiefly in the state of casts) which do not seem to occur in the underlying sands. Mr. Rhodes, the Fossil Collector of the Survey, was sent to collect from Rye Hill, and the list at the end of the Chapter has been prepared partly from the species so obtained, and partly from a careful inspection of the collections at Jermyn Street, Cambridge, Devizes, and other places.

The Chert Beds are quarried for road-material at Longbridge Deverill, Sutton-Veny, and Boreham. Fossils are not abundant in these beds, but *Pecten asper* and *P. orbicularis* were found

at Longbridge Deverill, and *Cardiaster fossarius* at Sutton-Veny. The first exposure of them is in the large quarry by Boreham Grange, two miles E.S.E. of Warminster. In 1889 this showed the following strata:—

	Ft.	In.
Dark sandy soil passing down into a greensand with a layer of small calcareous nodules	4	0
Blocks of hard calcareous glauconitic sandstone	0	9
Dark greensand with a layer of calcareous sandstone nodules in the middle	4	6
Blocks of hard, compact and crystalline limestone in greenish sand	1	0
Irregular layers of light-coloured siliceous stone with lenticules of black chert	2	0
Soft greensand	1	0
Soft grey silty spiculiferous sand, drying nearly white, with nodules of dull bluish-grey chert	1	0
Discontinuous layers of grey silt and hard chert	3	0
Greensand with fossils, 9 inches to	1	0
Layers of grey sand and striped chert, with a thick bed of chert at the bottom	4	0
	22	3

Pecten asper and *P. orbicularis* occurred in the greensand near the bottom. The bedding is nearly horizontal. It is interesting to notice that glauconitic sands with layers of calcareous stone come in here above the beds of chert and spiculiferous sand. A small pit north of the Grange shows marly soil with fossils and phosphates derived from the Chloritic Marl overlying 9 feet of dark greensand which is probably the same as that seen at the top of the larger quarry. This sand seems to occupy the place of the Rye Hill fossiliferous sand, but does not resemble it in colour, and *Holaster lævis* with a fragment of *Ammonites varians* were the only fossils seen in it.

The lower part of the Chert Beds and the underlying greensands are exposed to the south of Warminster in the lane leading from Oldfield Farm to Henfords Marsh. Near the top of the cutting there are beds of greensand and hard grey chert; lower down about 10 feet of buff-coloured spiculiferous silt and whitish siliceous stone with calcareous concretions are seen; and still lower is a sand pit showing the following section:—

	Feet.
Soil with fragments of chert	2
Buff coloured silty sand with two courses of cherty stone	5
Green sand with lumps of calcareous stone	5
Coarser greensand partly cemented by calcite with masses of greensand-rock, containing fossils	2
Loose greensand, seen for	2
	16

The fossils found here in the greensand-rock were *Pecten asper*, *P. orbicularis*, *P. Galliennei*, and *Neithea quadricostata*.

The same bed with a similar band of fossiliferous rock can be seen in a pit on the east side of the river Wily, opposite Longbridge Deverill church, some 20 feet of greensand with *Exogyra conica* being there shown below the rock-bed, which is the lowest bed in which *Pecten asper* has been found.

Greenish grey sands, with large calciferous burrstones, containing *Exogyra conica* and *Neithea æquicostata*, are seen in a small pit on Warminster Common, and it was from pits at that place that most of the siliceous sponges, for which Warminster was famous, were obtained.

Passing northward towards Westbury, it would appear that he Chert Beds and spiculiferous sands are greatly reduced, and are partly represented by glauconitic sands with layers and doggers of calcareous sandstone.

At Dilton, about two miles south-west of Westbury, a cutting at the cross-roads west of the church shows six feet of greensand, with layers of clear brown chert overlying two feet of yellowish greensand, containing many small brown phosphatic nodules, and below this are the yellowish micaceous sands of the *Am. rostratus* zone.

Two hundred yards south of this is a small sandpit about eight feet deep in yellowish-green sand, with two courses of chert and several large blocks of hard glauconitic limestone of a reddish tint. As the dip is southward, these beds probably succeed the last mentioned. Still further south is another sandpit which shows the following section:—

		Feet.
	3. Sandy chalk, with phosphatic nodules and *Stauronema Carteri*, the upper part hard, softer below and passing into the next	4
Warminster Beds.	2. Greyish greensand like that of Rye Hill, and containing a few fossils -	2½ to 3
	Nodules of hard calcareous stone at intervals.	
	1. Dark-greensand with irregular masses of hard calcareous sandstone	4

This section resembles that of Rye Hill more than any other in the district, and the following fossils were found in bed 2:—

Pleurotomaria.
Trochus.
Pecten asper.
Spondylus striatus.
Rhynchonella grasiana.
Terebratula biplicata.
Discoidea subuculus..

The following is a revised list of the fossils of the Warminster Beds, based on the lists published in the Geological Magazine for 1896. The letter s signifies obtained by the Geological Survey, o that the fossil is preserved in the British Museum, Woodwardian Museum, or some other collection.

Fossils of the Warminster Beds.

———	Lower Sands		Chert Beds.		Rye Hill Sands.	
Reptilia.						
Ichthyosaurus campylodon, *Carter*	–	–	–	–	s	–
Polyptychodon interruptus, *Owen*	–	–	–	–	s	
Pisces.						
Anomœodus augustus, *Ag.* (=Cœlodus cretaceus, *Ag.*)	–	–	–	–	s	–
Cœlodus sp. - -	s	–	–	–	–	–
Corax falcatus, *Ag.* -	–	–	–	–	s	–
Edaphodon crassus, *Newton*	–	–	–	–	s	
Enchodus lewesiensis, *Mant.*	–	–	–	–	s	
Lamna appendiculata, *Ag.* -	–	–	–	–	s	–
" macrorhiza, *Cope* - -	s ?	–	–	–	s	–
Oxyrhina Mantelli, *Ag.* - -	s	–	s	–	s	–
Plethodus expansus, *Dixon*	–	–	–	–	s	–
Protosphyræna ferox, *Leidy*	–	–	–	–	s	–
Ptychodus decurrens, *Ag.*	–	–	–	–	s	–
Scapanorhynchus subulatus, *Ag.* -	–	–	–	–	s	–
Cephalopoda.						
Ammonites complanatus, *Sow* = (A. largilliertianus, *d'Orb.*)	–	–	–	–	–	o
" falcatus, *Mant.*	–	–	–	–	s	–
" " var. curvatus, *Mant.*	–	–	–	–	s	–
" Mantelli, *Sow.*	–	–	–	–	s	–
" navicularis, *Mant.*	–	–	–	–	–	o
" planulatus, *Sow.*	–	–	–	–	–	o
" varians, *Sow.* -	–	–	–	–	s	–
" " var. Coupei, *Brong.*	–	–	–	–	s	–
Baculites baculoides, *d'Orb.* -	–	–	–	–	s	–
Hamites Parkinsoni ?, *Flem.*	–	–	–	–	–	o
" sp. -	–	–	–	–	s	–
Turrilites Morrisi, *Sharpe*	–	–	–	–	–	o
" Wiesti, *Sharpe* -	–	–	–	–	–	o
Belemnites ultimus, *d'Orb.* - - -	–	–	–	–	s	–
" sp. - - - - -	s	–	s	–	–	
Nautilus deslongchampsianus, *d'Orb.* -	–	–	–	–	s	–
" expansus, *Sow.* - -	–	–	–	–	–	o
" largilliertianus, *d'Orb.* - -	–	–	–	–	–	o
" lævigatus, *Sow.* -	–	–	–	–	–	o
Gasteropoda.						
Aporrhais oligochila, *Gard.*	–	–	–	–	–	o
" sp. -	–	–	–	–	s	
Dentalium rotomagense ?, *d'Orb.*	–	–	–	–	s	
Fusus bilineatus ?, *P & R.* (= Murex)	–	–	–		–	o
Littorina or Trochus - - -	–	–	–		–	o
Pleurotomaria brongniartiana, *d'Orb.*	–	–	–	–	–	o
" mailleana, *d'Orb.* -	–	–	–	–	–	o

Fossils of the Warminster Beds—cont.

———	Lower Sands.		Chert Beds.		Rye Hill Sands.	
Gasteropoda—cont.						
Pleurotomaria perspectiva, *Mant.*	–	–	–	–	–	o
„ cf. Thurmanni, *P. & R.*	–	–	–	–	–	o
„ sp.	–	–	–	–	s	–
Solarium ornatum, *Sow.*	–	–	–	–	–	o
„ dentatum ? *d'Orb.*	–	–	–	–	–	o
Scalaria sp. (casts)	–	–	–	–	s	–
Trochus variabilis ? *Seeley.*	–	–	–	–	–	o
„ sp. (casts) -	–	–	–	–	–	o
Turritella, sp. -	–	–	–	–	s	–
Lamellibranchiata.						
Anomia cf. convexa, *Sow.* -	–	–	–	–	s	–
„ cf. radiata, *Sow.* - -	–	–	–	–	s	–
Arca (Cucullæa) mailleana, *d'Orb.* -	–	–	–	–	s	–
Avicula gryphæoides, *Sow.* - -	s	–	s	–	s	–
„ sp. - - - -	s	–	–	–	–	
Crassatella regularis ? *d'Orb.*	–	–	–	–	s	–
Cyprina quadrata, *d'Orb.*	–	–	–	–	s	–
Cypricardia, sp. -	–	–	–	–	s	–
Exogyra conica, *Sow.* -	s	–	s	–	s	o
„ haliotoidea, *Sow.* -	–	–	–	–	–	o
Inoceramus latus, *d'Orb.* (*non Mant.*) -	–	–	–	–	s	–
„ sp. -	s	–	–	–	s	–
Lima aspera ? *Mant.*	–	–	–	–	s	o
„ cenomanensis, *d'Orb.*	–	–	–	–	s	o
„ elongata ? *Sow.*	–	–	–	–	s	o
„ globosa, *Sow.* -	–	–	–	–	s	o
„ ornata, *d'Orb.* -	–	–	–	–	s	o
„ rotomagensis, *d'Orb.*	–	–	–	–	s	–
„ semiornata, *d'Orb.*	–	–	–	–	s	o
„ semisulcata, *Sow.* -	s	–	s	–	–	–
„ sp. - - - -	–	–	–	–	s	–
Lucina sp. - -	–	–	s	–	–	–
Lithodomus - -	–	–	–	–	s	–
Modiola sp. - -	–	–	–	–	s	–
Ostrea canaliculata, *Sow.* (= *O. lateralis*)	–	–	–	–	s	o
„ frons, Park. (= *O. carinata, Sow.*)	–	–	–	–	s	o
„ vesicularis, *Lam.* - - -	–	–	–	–	s	o
„ vesiculosa, *Sow.* -	s	–	s	–	–	–
Pecten asper, *Lam.* - -	s	–	s	–	s	o
„ elongatus ? *Lam.* - -	–	–	–	–	s	o
„ cf. fissicosta, *Eth.*	–	–	–	–	–	o
„ Galliennei, *d'Orb.*	s	–	s	–	s	o
„ hispidus, *Goldf.*	–	–	–	–	s	o
„ orbicularis, *Sow.* - -	s	–	s	–	s	o
„ puzosianus, *d'Orb.* - -	–	–	–	–	s	–
„ (Hinnites) sp. - -	–	–	–	–	s	–
„ (Neithea) æquicostatus, *Lam.* -	–	–	–	–	s	–
„ „ cometa, *d'Orb.* - -	–	–	–	–	s	o
„ „ quadricostatus, *Sow.* -	s	–	s	–	–	–
„ „ quinquecostatus, *Sow.*	s	–	s	–	s	o
Plicatula inflata, *Sow.* - - -	–	–	–	–	s	o

Fossils of the Warminster Beds—cont

	Lower Sands.		Chert Beds.		Rye Hill Sands.	
Lamellibranchiata—cont.						
Pholadomya	–	–	–	–	s	–
Pleuromya -	–	–	–	–	s	–
Solecurtus -	–	–	–		s	–
Spondylus striatus, *Sow.* - -	–	–	–	–	s	o
„ dutempleanus ? *d'Orb.*	–	–	–	–	–	o
Trigonia aliformis, *Park.*	–	–	–	–	s	o
„ vicaryana ? *Lyc.* -	–	–	–	–	s	o
Brachiopoda.						
Argiope megatrema, *Sow.*	–	–	–	–	–	o
Lingula subovalis, *Dav.*	–	–	–	–	s	o
Kingena (Megerlia) lima, *Defr.*	–	–	–	–	s	o
Rhynchonella dimidiata, *Sow.*	–	–	–	–	s	o
„ „ var. convexa, *Sow*	–	–	–	–	s	o
„ grasiana, *d'Orb.*	–	–	–	–	s	o
„ mantelliana, *Sow.* - -	–	–	–	–	s	o
„ Martini, *Mant* -	–	–	–	–	s	o
„ Schloenbachi, *Dav.*	–	–	–	–	–	–
Terebratula biplicata, *Sow.* -	–	–	–		s	o
„ obesa, *Sow.*	–	–	–	–	s	o
„ ovata, *Sow.*	–	–	–	–	s	o
„ phaseolina ? *Lam.*	–	–	–	–	–	o
„ squamosa, *Mant.*	–	–	–		s	–
Terebratulina triangularis, *Ether.*	–	–	–	–	s	–
„ striata, *Wahl.*	–	–	–	–	s	o
Terebratella Menardi, *d'Orb.*	–	–	–		–	o
„ pectita, *Sow.*	–	–	–		s	o
Terebrirostra lyra, *Sow.* - -	–	–	–		s	o
Waldheimia (like Juddi, *Walker*)	–	–	–	–	s	–
Polyzoa.						
Bidiastopora lamellosa, *d'Orb.*	–	–	–	–	s	–
Ceriopora polymorpha, *Goldf.*	–	–	–	–	s	–
Choristopetalum impar, *Lons.*	–	–	–	–	s	–
Clausa francquana, *d'Orb.*	–	–	–	–	s	–
„ micropora, *d'Orb.* -	–	–	–	–	s	–
Diastopora Sowerbyi, *Lons.*	–	–	–	–	s	–
„ tubulus ? *d'Orb.* -		–	–	–	s	–
Entalophora cenomana, *d'Orb.*		–	–	–	s	–
„ ramosissima, *d'Orb.*	–	–	–	–	s	–
„ sp. - - -	s	–	–	–	s	–
Eschara cybele ? *d'Orb.* - -	–	–	–	–	s	–
„ sp. - -						
Radiopora pustulosa, *d'Orb.* -	–	–	–		s	–
Spiropora cenomana, *d'Orb.* -	–	–	–	–	s	–
Truncatula pinnata, *Rœm.* - -	–	–	–	–	s	–

Fossils of the Warminster Beds—cont.

———	Lower Sands.		Chert Beds.		Rye Hill Sands.	
Crustacea.						
Cyphonotus incertus, *Carter*	–	–	–	–	–	o
Hemioon Cunningtoni, *Bell*	–	–	–	–	–	o
Necrocarcinus Bechei, *Deslong.*	–	–	–	o[1]	s	o
" glaber, *Woodw.*	–	–	–	o[1]	–	–
" tricarinatus, *Bell*	–	–	–	o[1]	–	o
" Woodwardi, *Bell*	–	–	–	o[1]	–	o
Plagiophthalmus oviformis, *Bell*	–	–	–	–	–	o
Xanthosia gibbosa, *Bell*	–	–	–	–	–	o
Pollicipes sp.	–	–	–	–	s	–
Scalpellum lineatum, *Darw.*	–	–	–	–	s	–
Annelida.						
Ditrupa difformis, *Lam.*	s	–	s	–	s	o
Serpula ampullacea, *Sow.*	–	–	–	–	s	o
" annulata, *Reuss*	–	–	–	–	s	–
" antiquata, *Sow.*	s	–	s	–	s	o
" filiformis, *Sow.*	–	–	–	–	s	o
" ilium, *Sow.*	–	–	–	–	s	–
" macropus, *Sow.*	–	–	–	–	s	–
" plana, *Woodw.*	–	–	–	–	s	–
" plexus, *Sow.*	–	–	–	–	s	o
" (Vermicularia) concava, *Sow.*	s	–	s ?	–	s	o
" " umbonata, *Sow.*	s ?	–	s	–	s	–
Echinodermata.						
Antedon paradoxus	–	–	–	–	s	–
Caratomus rostratus, *Ag.*	–	–	–	–	s	o
Cardiaster fossarius, *Benett.*	s	–	s	–	–	o
" Perezi, *Sism.*	–	–	–	o	–	–
Catopygus columbarius, *Lam.*	–	–	–	–	s	o
" pyriformis, *Goldf.*	–	–	–	–	s	–
Cidaris velifera, *Ag.*	–	–	–	–	–	o
" vesiculosa, *Goldf.*	–	–	–	–	s	o
Cottaldia Benettiæ, *Kœnig*	–	–	–	–	s	o
Discoidea subuculus, *Klein*	s	–	s	–	s	o
Echinobrissus lacunosus, *Goldf.*	–	–	–	–	s	o
" Morrisi, *Forbes*	–	–	–	–	–	o
Echinocyphus difficilis, *Ag.*	–	–	–	–	s	o
Echinospatagus Collegnii, *Sism.*	–	–	–	o	–	–
Epiaster Lorioli, *Wright*	–	o	–	o	–	–
Glyphocyphus radiatus, *Hœn.*	–	–	–	–	–	o
Goniophorus lunulatus, *Ag.*	–	–	–	–	s	o
Hemiaster minimus, *Ag.*	–	–	–	–	s	o
Holaster lævis, *Ag.*	s	–	s	–	s	o
" subglobosus, *Leske*	–	–	–	–	s	o

[1] These crabs were all found in a quarry near Maiden Bradley by Mr J. Scaues. N. glaber was described by Dr. H. Woodward in Geol. Mag., Dec. 4, vol. v., p. 302 (1898)

Fossils of the Warminster Beds—cont.

——	Lower Sands.		Chert Beds.		Rye Hill Sands.	
***Echinodermata*—cont.**						
Peltastes clathratus, *Ag.*	–	–	–	–	s	o
„ umbrella, *Ag.*	–	–	–	–	s	o
Pentacrinus Agassizi, *Hagenow*	–	–	–	–	s	o
Pseudodiadema Benettiæ, *Forbes*	–	–	–	–	s	o
Pseudodiadema Michelini, *Ag.*	–	–	–	–	s	o
„ Rhodani, *Ag.*	–	–	–	–	s	o
„ variolare, *Brong.*	–	–	s	–	–	–
Pyrina lævis, *Ag.*	–	–	s	–	–	o
Salenia Desori, *Wright*	–	–	–	–	–	o
„ gibba, *Ag.*	–	–	–	–	–	o
„ Lorioli, *Wright*	–	–	–	–	–	o
„ petalifera, *Desor.*	–	–	–	–	s	o
„ sp.	–	–	s	–	–	–
Actinozoa.						
Astrocœnia decaphylla, *E. & H.*	–	–	–	–	s	o
Micrabacia coronula, *Goldf.*	–	–	–	–	s	o
Stephanophyllia Bowerbanki, M. Ed.	–	–	–	–	s	o
Trochosmilia sp.	–	–	–	–	s	–
Hydrozoa.						
Parkeria	–	–	–	–	–	o
***Spongida* (*calcareous*).**						
Corynella rugosa, *Hinde*	–	–	–	o	–	–
„ socialis, *Hinde*	–	–	–	o	–	–
Elasmostoma consobrinum, *d'Orb.*	–	–	–	o	–	–
„ normannianum, *d'Orb.*	–	–	–	o	–	–
Manon peziza, *Goldf.*	–	–	–	–	s	–
Pachytilodia infundibuliformis, *d'Orb.*	–	–	–	o	–	–
Peronidella furcata, *Goldf.*	–	–	–	o	–	–
Pharetrospongia Strahani, *Sollas*	–	–	–	o	–	–
Porosphæra urceolata, *Phil.*	s	–	–	–	s	o
„ sp.	s	–	s	–	–	–
Tremacystia Orbignyi, *Hinde*	–	–	–	–	s	o
„ siphonioides, *Mich.*	–	–	–	–	s	–
***Spongida* (*siliceous*).**						
Carterella cylindrica, *Zitt.*	–	–	–	?[1]	–	–
Chenendopora Michelini, *Hinde*	–	–	–	o	–	–
„ obliqua, *Benett.*	–	–	s	–	–	–

[1] Mr. Cunnington informs me that it is doubtful whether this species has been found near Warminster. So far as he knows it occurs only at Savernake (see p. 265).

Fossils of the Warminster Beds—cont.

	Lower Sands.		Chert Beds.		Rye Hill Sands.	
Spongida (Siliceous)—cont.						
Doryderma Benetti, *Hinde*	–	–	s	o	–	–
„ dichotomum, *Benett*	–	–	s	o	–	–
Hallirhoa agariciformis, *Benett*	–	–	s	o	–	–
„ costata, *Lam.* & vars.	–	–	s	o	–	–
Holodictyon capitatum, *Hinde*	–	–	–	o	–	–
Jerea Websteri, *Sow.*	–	–	–	o	–	
„ reticulata, *Hinde*	–	–	–	o	–	
Jereica cylindrica, *Hinde*	–	–	–	o	–	–
Kalpinella pateriformis, *Hinde*	–	–	s	o	–	–
Kalpinella rugosa, *Hinde*	–	–	–	o	–	–
Nematinion calyculatum, *Hinde*	–	–	–	o	–	–
Pachypoterion compactum, *Hinde*	–	–	–	o	–	–
„ robustum, *Hinde*	–	–	–	o	–	–
Polyjerea arbuscula, *Hinde*	–	–	–	o	–	–
„ lobata, *Hinde*	–	–	–	o	–	
Sclerokalia Cunningtoni, *Hinde*	–	–	–	o	–	
Siphonia tulipa, *Zitt.*	–	–	–	o	–	
Rhopalospongia gregaria, *Benett*	–	–	–	o	–	–
„ obliqua, *Hinde*	–	–	–	o	–	–
Trachysycon nodosum, *Hinde*	–	–	–	o	–	–

CHAPTER XVII.

GAULT AND UPPER GREENSAND (SELBORNIAN), OF DEVIZES AND THE VALE OF PEWSEY.

General Description.

The general structure of the Vale of Pewsey is similar to that of the Vale of Wardour. It is an anticline, with very high dips along the greater part of its northern border and low dips on the southern side. But as the drainage escapes through the southern hills instead of through its eastern end, as in the case of the Vale of Wardour, the arrangement of the outcrops is different. The valley has not been cut down to so low a base level, and its floor is occupied almost from end to end by the sands which overlie the Gault.

At its western end these sands form a high plateau which bears several outliers of Lower Chalk and terminates in steep slopes towards the west. Descending these slopes one passes rapidly over the outcrops of the micaceous sandstone, malmstone, and gault clay. The town of Devizes stands on the edge of this plateau at a height of about 400 feet above the sea.

The outcrop of the Gault does not, therefore, enter the Vale itself, but passes along its western margin and round the head of a valley which indents this margin as far as Stert and Urchfont.

Although general descriptions of the Gault and Greensand near Devizes were given by Lonsdale[1] and Fitton,[2] yet they did not distinguish any regular succession of beds in the Greensand The first to do this was Prof. Ch. Barrois,[3] who recognised the micaceous sandstone as the rock known in France by the name of *gaize*, and correctly referred it to the zone of *Ammonites rostratus*. He also separated the higher sands as part of his zone of *Pecten asper*.

The succession was subsequently described by the present writer in a paper on the "Geology of Devizes," under the heads of (1) Gault, (2) Malmstone, (3) Greensands.[4]

The Gault is about 90 feet thick, and is throughout a silty, micaceous clay. Near the base it is loamy and yellowish in colour, higher up it becomes more argillaceous and grey or lilac-coloured, with reddish layers in some places, and the highest part is always dark grey, with much fine sand and some small glauconite grains. Two zones can be distinguished in it, the

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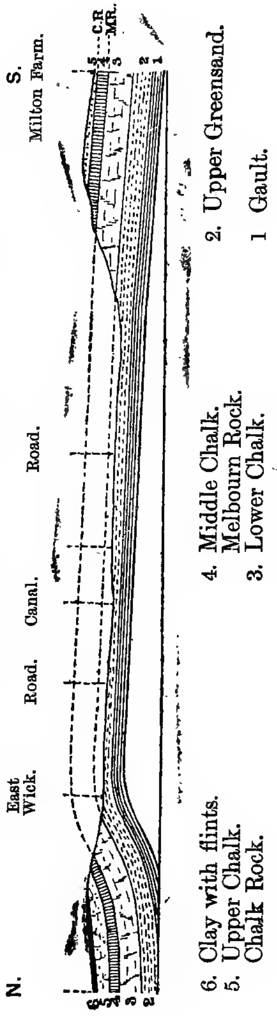
[1] Trans. Geol. Soc. Ser. 2, vol. iii., p. 268.
[2] Trans. Geol. Soc. Ser. 2, vol. iv., p. 261.
[3] Recherches sur le Terr. Crét. de l'Angleterre, 1876, p. 59.
[4] Wiltshire Arch. and Nat. Hist. Mag., vol. xxv., p. 317, and Proc. Geol. Assoc., vol. xii., p. 254 (1892).

lower beds being characterised by *Ammonites interruptus*, *Am. benettianus*, and *Am. Beudanti*, the higher beds by *Am. lautus*, *Am. tuberculatus*, and *Am. splendens*. It is of special interest to note that this succession agrees with that in the Lower Gault

FIG. 69.—*Section across the Vale of Pewsey.*

Horizontal Scale—one mile to an inch. Vertical Scale—1600 feet to an inch.



of Folkestone, and that none of the Wiltshire Gault corresponds with the Upper Gault of Folkestone.

MALMSTONE succeeds the Gault, as in the district previously described, but is still an earthy malmstone, dull grey when wet, and drying to a very light grey like Chalk Marl. Its thickness

seems to vary, probably from 10 to 16 feet, but there is no exposure of the whole depth of it at any one place, and it passes down into sandy marl and upward into micaceous sandstone. No fossils but *Serpula (Vermicularia) concava* and *Avicula gryphæoides* have been found in it.

The fine micaceous sandstone into which the malmstone passes only differs from it in containing less organic silica and a larger proportion of the inorganic constituents—quartz, mica, and glauconite. It is, in fact, identical with the rock which is known as "Gaize" in France. This sandstone has yielded a large number of fossils, but in weathered exposures the fossils are generally very friable. The prevalent Ammonites are *Am. rostratus* and *Am. auritus*. Other common fossils are *Pleuromya mandibula*, *Cytherea plana*, *Thetis Sowerbyi*, *Cucullæa carinata* and *Serpula (Verm.) concava*. Of this sandstone there is generally from 30 to 40 feet.

The upper part of the sandstone is soft and friable, and passes up into fine grey sands, which contain large doggers or "burr-stones" of calcareous sandstone; above these sands is a continuous layer of hard darker grey calcareous sandstone, or sandy limestone, which has been quarried for building-stone at Potterne, and has been called the Potterne rock.[1] It has yielded many fossils, the fauna being nearly the same as that in the sandstone below.

All these beds unquestionably belong to the zone of *Ammonites rostratus*, and they have a collective thickness of 80 or 90 feet.

Green sands.—Above the Potterne rock there is, near Devizes, from 60 to 70 feet of glauconitic sand (without mica), containing several courses of greenish calcareous sandstone. These seem to occupy the place of the Green sands and Chert Beds of the Warminster district. It is possible, however, that the lower 30 feet should be included in the zone of *Ammonites rostratus*, for these sands contain so few fossils except small oysters and the ubiquitous *Pecten orbicularis*, that palæontological evidence fails us. Locally there is a convenient line of separation at a conspicuous layer of calcareous grit to which large grains of glauconite impart a speckled appearance, and which near Devizes lies about 30 feet above the "Potterne rock." This "speckled" stone can be identified at many places to the south and east of Devizes, and *Pecten asper* has been found in it near Market Lavington. It is true that a single specimen of *Ammonites rostratus* has been found in what seems to be this bed at Stert, but this may only indicate a mingling of the two faunas at their line of junction.

The general succession south of Devizes is as follows:—

		Feet.
3.	Greensands with layers of glauconitic sandstone -	30
2.	Green and grey sand, with beds of grey stone -	30
	Micaceous sand and sandstone, passing down into malmstone - -	80–90
1.	Grey micaceous marl and clay (Gault) - -	90

[1] Proc. Geol. Assoc., vol. xii., p. 257.

STRATIGRAPHICAL DETAILS.

Gault.

There is a brickyard near West Farm, about a mile north-west of Market Lavington, in grey micaceous clay, which is apparently well suited for making into tiles and flower-pots, but the only fossil seen was *Natica Genti*.

A better section is that in the Caen Hill brickyard, west of Devizes, where the following beds were visible in 1888:—

	Feet.
Soil and made ground	3
Bluish-grey clay	4
Layer of yellowish ferruginous concretions	1
Dark lilac-coloured micaceous clay with scattered septarian phosphatic nodules from the size of a walnut to that of a cocoanut	15
	23

Fossils are not common, but fragments of *Am. interruptus* occur in the clay and in the concretionary layer. Mr. W. Cunnington has also obtained the following:—

Ammonites Beudanti.	Nucula bivirgata.
Rostellaria carinata.	„ capsæformis.
Cucullæa carinata.	„ ovata.
Cardita sp.	„ pectinata.
Pecten orbicularis.	Trochosmilia sulcata.
Inoceramus sp.	Serpula concava.

There is another pit (not now worked) on the road from Devizes to Rowde, which may be in slightly lower beds than those seen at Caen Hill. The clay here contains much selenite.

There was formerly a brickyard at Dunkirk, on the same road, but just below the base of the Malmstone, and I am informed by Mr. W. Cunnington that the clay dug there was grey, marly and shaly, and that he had obtained the following fossils from it:—

Ammonites lautus.	Lima parallela.
„ splendens.	Inoceramus sulcatus (rare).
„ tuberculatus.	„ concentricus.
Natica Genti.	Pecten orbicularis.
Cucullæa carinata.	Pinna tetragona.
Avicula sp.	Ostrea vesicularis.
Exogyra haliotoidea.	Pleuromya mandibula.
Cardita sp.	Trigonia Fittoni.

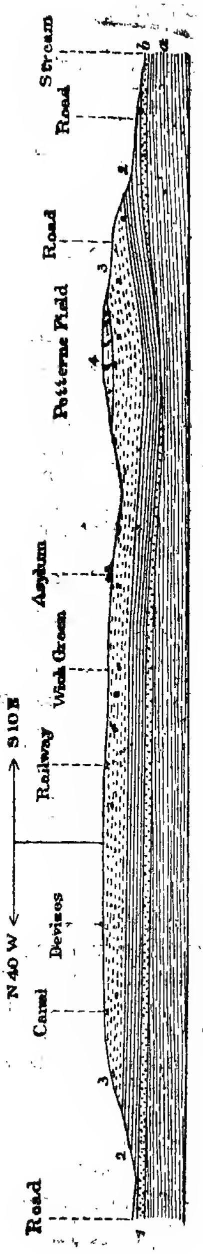
Upper Greensand (Devizes Beds).

A good section of these beds can be seen in an old pit, now the garden of some cottages on the eastern side of the high road about a mile N.W. of Lavington, the section seen in 1888 being as follows:—

	Feet.
Sandy soil	2
Soft yellowish grey micaceous sandstone	10
Hard grey calcareous malmstone	1
Softer grey sandy malmstone, seen for	5

FIG. 70.—*Section through Devizes and Potterne Field.*

Horizontal Scale—two inches to a mile. Vertical Scale—880 feet to an inch.



4. Lower Chalk.
3. Upper Greensand, about 150 feet.
2. Gault, about 90 feet.

b. Lower Greensand.
a. Portland Beds and Kimeridge Clay.

In the sandstone *Ammonites auritus, Pleuromya mandibula,* and *Thetis Sowerbyi* were found.

In the long road-cutting descending the hill to the southward higher beds are seen, the succession being as follows:—

	Feet.
4. Hard glauconitic calcareous sandstone, whitish, speckled with green grains - - -	1
3. Green and grey laminated sands with whitish pipings	30
2. Hard grey fine-grained sandstone, Potterne rock-bed - -	1½
1. Fine grey sands with *Ostrea vesiculosa,* about	30
	over 60

The lamination and current-bedding of the sands (No. 3) are very marked, the green layers being darker from the larger proportion of glauconite grains, and some of the beds are laminated obliquely. I did not find any fossils in them.

The speckled sandstone is that which has been mentioned on page 251 as probably the base of the *Pecten-asper* zone.

More complete sections of the malmstone, micaceous sandstone, and grey sands can be seen in Fiddington Lane and the lane west of Wickham Green, which are both deeply cut through the escarpment formed of the outcrop of the sandstones. There are also good sections in the deep cut lanes at and near the village of Urchfont, where *Cucullæa carinata* and *Cytherea plana* are not uncommon; the sandstone is also exposed to the east of Stert, and Prof. Barrois got many fossils there.

Near Potterne, south of Devizes, there are also many road-cuttings which give good sections of the sandstone, as, for instance, in the lane to Potterne Wick, where nearly 40 feet can be measured, and in Stroud Lane, east of the village. The outcrop of the Potterne Rock is visible at the top of Stroud Lane, and can be followed along the road which leads thence to Potterne; it was formerly dug in a field north of Blount's Court Farm, and many fossils were obtained, some of which are in the Devizes Museum, and others in the collections at Jermyn Street and South Kensington.

Passing from Potterne to Devizes (Fig. 70), an excellent section is afforded by the road-cutting up the hill to Devizes. At the bottom of this hill and near the lodge at the entrance to Broadleas is a small pit in tough grey malmstone containing *Avicula gryphæoides* and *Serpula (Verm.) concava.* At the beginning of the road cutting sandy malmstone is seen, and a little above[1] there is a continuous section showing first soft yellowish micaceous sandstone containing large round calcareous "burr-stones." The upper part of this sandstone has a yellowish-green tint, and rapidly passes up into soft greenish-grey sand containing more glauconite and less mica than the sandstone below: of this sand there is about 4 feet, and it is succeeded by a hard dark-grey calcareous rock which forms a continuous course from 18 to 20 inches in thickness. This is the Potterne rock.

[1] The lower and more fossiliferous part of the sandstone appears to be overgrown and concealed.

Above the Potterne rock comes greenish-grey sand with whitish pipings and mottlings for about 20 feet, then a course of calcareous doggers, succeeded by about 10 feet of bright greensand. Above this lies a nearly continuous course of hard sandstone about a foot thick, light grey in colour, speckled with large grains of green glauconite and traversed by many long stem-like bodies resembling stems of *Siphoniæ*. This is the same bed as that seen in the cutting near Lavington.

Good sections of the fossiliferous sandstone were exposed when the railway was made and when the Caen Hill road was cut west of Devizes, but these are now overgrown. It may, however, be examined on the road to Dunkirk, where I obtained *Ammonites rostratus*, *Am. varicosus*, *Pleuromya mandibula*, and other fossils.

The following list of fossils from the micaceous sandstone at and near Devizes, and from the grey rock of Potterne is based on the collections at Devizes and at Jermyn Street. The fossils in the former were named by me, those in Jermyn Street by Mr. Newton:—

——	Devizes Gaize.	Potterne Rock.	Gaize of France.
Pisces.			
Lamna appendiculata, *Ag.*	x	–	x
Oxyrhina sp. -	x		–
Protosphyræna ferox, *Leidy.*	x	–	–
Cephalopoda.			
Belemnitella sp. -	x	–	?
Nautilus clementinus, *d'Orb.*	x	–	x
" deslongchampsianus, *d'Orb.*	x	–	–
" elegans, *Sow.* -	x	–	–
" Fittoni, *Sharpe*	x	–	?
" semiundatus, *Foord*	x	–	–
" sublævigatus, *d'Orb.*	x	–	x
" undulatus, *Sow.*	x	x	–
" ventroplicatus, *Foord*	x	–	–
" (mandibles = Rhynchoteuthis)	x	–	–
Ammonites auritus, *Sow.*	x	x	x
" " var. catillus, *Sow.*	x	x	x
" denarius, *Sow.* -	x	–	–
" cf. Deshayesi, *Leym.*	–	x	–
" Goodhalli, *Sow.*	x	–	–
" hugardianus, *d'Orb.* -	x	–	–
" interruptus ?, *Brug.*[1]	x	–	–
" planulatus, *Sow.* -	x	–	–
" renauxianus, *d'Orb.* -	x	–	x
" rostratus, *Sow.* (=inflatus)	x	x	x

[1] Mr. E. T. Newton informs me that there are two specimens in the Jermyn Street Museum which seem to be referable to this species, though they are more or less crushed. They differ from *A. splendens* and *A. denarius*.

——	Devizes Gaize.	Potterne Rock.	Gaize of France.
Cephalopoda—cont.			
Ammonites splendens, *Sow.*	x	x	x
„ varicosus, *Sow.*	x	–	–
Anisoceras armatus, *Sow.*	x	–	x
„ alternatus ?, *Mant.*	x	–	x
„ tuberculatus, *Sow.*	x	–	
Hamites desorianus, *Pict.*	x	–	–
„ elegans, *Park.*	x	–	
„ sp.	x	–	–
Helicoceras rotundus, *Sow.*	x	–	–
Toxoceras	x	–	–
Gasteropoda.			
Actæon affinis, *Sow.*	x	–	
Acmæa tenuicosta, *d'Orb.*	x	–	
Aporrhais calcarata, *Sow.*	x	–	–
„ Cunningtoni, *Gard.*	x	–	
„ histochila, *Gard.*	x	–	–
„ retusa, *Sow.*	x	–	–
Crepidula gaultina ?, *Buv.*	x	–	
Dentalium medium, *Sow.*	x	–	–
„ divisiense, *Gard.*	x		
Emarginula Gresslyi, *P. & C.*	x		–
„ divisiensis, *Gard.*	x	–	
Fusus clathratus, *Sow.*	x	x	x
Narica cretacea, *d'Orb.*	x	x	
Natica Genti, *Sow.* (=canaliculata)	x	x	x
Pleurotomaria Greppini, *P. & C.*	x	–	–
„ perspectiva ?, *Mant.*	x	x	–
„ sp.	x	–	–
Puncturella antiqua, *Gard.*	x	–	–
Pyrula Brighti, *Sow.*	x	–	–
Scalaria dupiniana, *d'Orb.*		x	–
„ rauliniana, *d'Orb.*	x	–	–
Solarium ornatum, *Sow.*	x	–	x
Turbo pictetianus, *d'Orb.* (=T.	x	x	x
nodosa, *Seeley*).			–
Turbo sp.	x		–
Turritella granulata, *Sow.*	x	–	–
Lamellibranchiata.			
Anomia lævigata, *Sow.*	x	x	–
„ radiata, *Sow.*	x	–	x
Anatina (cf. royana, *d'Orb.*)	x	–	–
Arca Galliennei ?, *d'Orb.*	x	–	–
„ sp. (cf. ligeriensis, *d'Orb.*)	x	x	–
„ pholadiformis ?, *d'Orb.*	x	–	
„ (Cucullæa) carinata, *Sow.*	x	–	x
„ „ glabra, *Park.*	x	x	x
„ sp.	x	x	–
Avicula gryphæoides, *Sow.*	x	–	x
„ rauliniana, *d'Orb.*	x	–	x
„ sp.	x	x	–
Cardium gentianum, *Sow.*	x	–	–
„ hillanum, *Sow.*	x	x	–
Cardita dupiniana (?), *d'Orb.*	x	–	x
„ tenuicosta, *Sow.*	x	x	x

——	Devizes Gaize.	Potterne Rock.	Gaize of France.
Lamellibranchiata—cont.			
Cyprina angulata, *Flem.*	–	x	–
„ quadrata, *d'Orb.*	–	x	–
„ regularis, *d'Orb.*	x	–	–
„ sp. - - - - -	x	–	–
Crassatella sp. (cf. Guerangeri, *d'Orb.*)	x	–	–
Cytherea plana, *Sow.* - - -	x	x	x
„ truncata, *Sow.* -	x	–	–
Exogyra haliotoidea, *Sow.* -	x	–	x
„ conica, *Sow.* -	x	x	–
Gervillia rostrata, *Sow.* ? -	x	–	–
Goniomya vilbersensis ?, *P. & C.* -	x	–	–
„ sp. - -	x	–	–
Inoceramus concentricus, *Park.*	x	x	–
„ (several species)	x	x	–
Isocardia crassicornis, *d'Orb.*	x	.	–
„ cryptoceras, *d'Orb.*	x	–	x
Leda (Nuculana) solea, *d'Orb.*	x	–	–
Lima Archiacana, *C. & Br.*	x	–	x
„ cf. albensis, *d'Orb.* -	–	x	x
„ Galliennei, *d'Orb.* -	x	–	–
„ parallela, *d'Orb.* (non *Sow.*) -	–	x	x
„ semisulcata, *Sow.*	–	x	–
„ new sp. - - -	x	–	–
Lucina lenticularis (?), *Goldf.* -	x	x	?
„ tenera, *Sow.* - -	x	–	–
Modiola ligeriensis, *d'Orb.* (or reversa, *Sow.*). -	x	x	–
„ sp. (not æqualis) -	x	–	
„ sp. (diversely striated) -	x	–	–
Mytilus siliqua, *d'Orb.* -	x	x	–
Nucula ovata, *Mant.*	x	–	x
„ pectinata, *Sow.*	x	–	–
Ostrea canaliculata, *Sow.*	x	–	x
„ frons, *Park.* (=carinata, *Sow.*)	x	–	–
„ vesiculosa, *Sow.*	x	x	x
„ vesicularis, *Sow.*	x	–	–
Pecten orbicularis, *Sow.*	x	x	x
„ raulinianus, *d'Orb.* -	x	x	x
„ sp. - - -	x	–	–
„ (Neithea) 4-costatus, *Sow.*	x	x	–
„ („) 5-costatus, *Sow.*	x	x	x
Perna -	x	–	–
Periploma -	x	–	–
Pinna decussata ?, *Goldf.*	x	–	–
„ tetragona, *Sow.* -	x	–	x
Pleuromya mandibula, *Sow.* -	x	x	x
„ plicata, *Sow.* -	x	x	x
„ Rhodani, *P. & Rx.*	x	–	–
Plicatula pectinoides, *Sow.* -	x	x	x
Pholadomya - - -	x	–	–
Siliqua moreana, *Buv.* - -	x	–	x
Sphæra sp. (Corbis) - -	–	x	–
Tellina inæqualis, *Sow.* -	x	–	
„ striatula, *Sow.* - -	x	–	–
Thetis Sowerbyi, *Röm.*	x	x	–

——	Devizes Gaize.	Potterne.	Gaize of France.
Lamellibranchiata—cont.			
Thracia sp.	x	–	–
Trigonia aliformis, *Park.*	–	x	–
„ carinata, *Ag.*	–	x	–
„ spinosa, *Park.*	x	–	x
„ scabricola, *Lyc.*	x	–	?
Unicardium ringmeriense, *Mant.*	x	–	–
Venus faba, *Sow.*	x	–	–
„ immersa, *Sow.*	x	–	–
„ ovalis ?, *Sow.*	x	–	–
„ rotomagensis ?, *d'Orb.*	–	x	x
„ sp.	x	–	–
Brachiopoda.			
Rhynchonella sp.	x	–	–
Terebratula biplicata, *Sow.*	x	x	x
„ ovata, *Sow.*	x	–	x
„ squamosa ?, *Mant.*	–	x	–
Bryozoa.			
Ceriopora polymorpha, *Goldf.*	–	x	–
„ sp.	x	–	–
Heteropora	x	–	–
Petalopora pulchella, *Röm.*	x	–	–
Radiopora pustulosa, *d'Orb.*	–	x	–
Crustacea.			
Pollicipes rigidus, *Sow.*	x	–	–
Hoploparia granulosa, *Bell*	x	–	–
„ Saxbyi, *McCoy*	x	–	–
„ scabra, *Bell*	x	–	–
Annelida.			
Serpula plexus, *Sow*	x	–	x
„ (Vermilia) ampullacea, *Sow.*	x	–	–
„ (Vermicularia) concava, *Sow.*	x	x	x
Echinodermata.			
Cardiaster fossarius [1], *Benett.*	x	–	–
„ latissimus, *Ag.*	x	–	–
„ sp. (? Perezii, *Sism.*)	x	–	–
Echinospatagus murchisonianus, *Mant.*	x	–	–
„ Quenstedti, *Wright*	x	–	–
Hemiaster	x	–	–
Holaster lævis, *de Luc.*	x	–	–

[1] The occurrence of this in these beds is doubtful.

Although I fully agree with Prof. Barrois that the Gaize of Devizes is on the same stratigraphical horizon as the Gaize of Argonne, the number of species which are known to occur in both is much smaller than one would have expected. The list of Devizes fossils above given contains 132 named species. Dr. Barrois' lists from the Gaize and nodules of Talmats and of Marlemont include 125 named species; yet only 44 occur without doubt in both lists. This may to some extent be due to diverse identifications, but there are certainly a large number in each list which do not occur in the other deposit; and the figures show the danger of trusting to percentages, for the two faunas are connected only by about one-third of the species in each.

Zone of Pecten asper and Cardiaster fossarius.

The speckled sandstone above described is not confined to the immediate neighbourhood of Devizes, but can be identified at many places to the southward and south-eastward. It can be seen in the lanes between Lavington and Easterton, where *Pecten asper* has been found in it, and in the main road north-east of Eastcott.

It is everywhere overlain by beds of sharp glauconitic sand, the grains of quartz and glauconite being larger than those in the underlying sands, and those of quartz more angular. Mr. W. Cunnington informs me that the remarkable sponge *Phymatella nodosa* was obtained from the sands near Lavington.

The higher part of the village of Urchfont stands on these sands, and a good section of the very highest beds can be seen in the lane which leads up to Urchfont Hill south of the village.

This exposure was described by Prof. Barrois[1] in 1876, but I find myself obliged to differ from his account in several important particulars. He saw a "deep and clear plane of erosion" (ravinement) where I see only a colour line, and he makes the dip seven degrees instead of about three degrees. The sands are shown in several small pits on the east side of the road. At the top of the highest of these is a hard calcareous grit or sandstone, consisting of large grains of quartz and glauconite, cemented by calcite and penetrated by cylindrical bodies like Siphonia stems: it also contains *Pecten asper*.

Below this rock are five feet of sharp greenish-grey sand, enclosing at the top lenticular lumps of hard whitish siliceous stone. The soft sand rests on a layer of large "doggers" of calcareous sandstone, consisting of the same sand (*i.e.*, quartz and glauconite), cemented by calcite and containing many *Pecten asper*. These "doggers" are so close to one another as to form an almost continuous layer, and about a foot lower is another course of similar masses, but more distant from each other; these are embedded in sand which is partly light green and partly dark green, the dark green running through both soft sands and hard stones for about twenty feet, but thinning out towards the north. Its base is clearly marked and slightly undulating, and this is the "ravinement" described by Barrois, but it is only a current-

[1] Recherches sur le Terrain. Cret. Sup. en Angleterre, &c., p. 60.

bedded layer containing more glauconite than the sand above and below.

The second and lower pit shows about five feet of sharp grey sand containing more quartz than glauconite, and below this is another course of hard "doggers." The complete succession here is therefore as follows:—

	Feet.
Chloritic Marl (well exposed).	
Hard glauconitic sandstone - -	1
Soft greenish-grey sand	5
Doggers of glauconitic sandstone - -	1
Greenish-grey sand with a layer of dark-green sand near the top, running partly through doggers	2
Green sands with two layers of large sandstone doggers	10

From these upper green sands near Devizes, small exposures of which have been laid open from time to time, the following fossils have been obtained:—

A compound coral.	Terebratula biplicata.
Catopygus columbarius.	Exogyra conica.
Holaster lævis.	„ vesiculosa.
Cardiaster fossarius.	Lima semisulcata.
Rhynchonella dimidiata.	Pecten asper.
„ grasiana.	Nautilus deslongchampsianus.

So far as I can learn *Pecten asper* has not been found at Devizes, though it is common to the south and also eastward in the Vale of Pewsey, another instance of the local and partial distribution of this Pecten.

Another good section of the upper part of the greensand is exposed in the railway-cutting at Stert, two miles S.E. of Devizes, and is important as showing a great local diminution in the highest sands.[1]

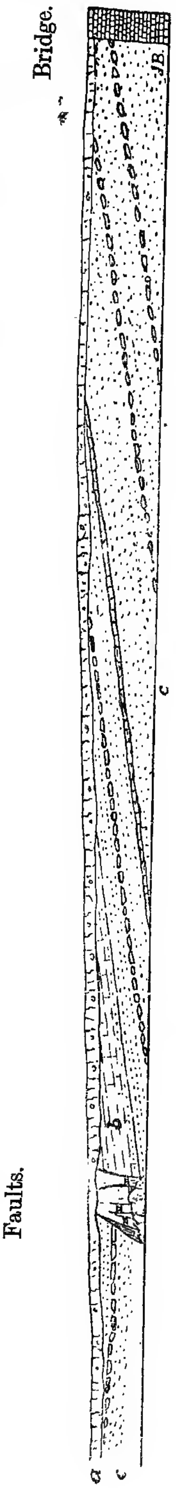
The western part of the cutting is in greensand, but about the middle a fault crosses the line and brings in the base of the Chalk Marl from beneath which the sands with four layers of calcareous sandstone rise eastward at an angle of about 7°. Fig. 71 shows this part of the section and is based on a drawing made by Mr. Codrington when the cutting was fresh and the fault-planes more clearly exposed. Between the faults and the bridge the descending succession is as follows:—

		Ft.	In.
Chalk -	Chalk Marl - - - - - - - - - -		
	Chloritic Marl with many phosphatic nodules	4	0
Upper Greensand	Light greensand, calcareous above, clean below, with *Pecten asper* - - -	6	0
	Course of rounded masses of glauconitic stone -		
	Glauconitic sand, no fossils seen - - about	8	0
	Continuous layer of sandstone, one *Am. rostratus* found - - - about	1	0
	Glauconitic sand with a layer of *Ostrea vesiculosa* - - about	14	0
	Course of large rounded doggers of glauconitic sandstone - - - - -	0	9
	Soft greensand - - - - - -	10	0
	Course of doggers, as before - - - - -	0	9
	Soft grey sand, passing under the bridge -		
		44	6

[1] See also Summary of Progress of Geological Survey for 1898, p 187.

FIG. 77.—*Section along the railway near Stert, Devizes.*

Horizontal Scale 120 feet to an inch. Distance about 300 yards. Vertical Scale 60 feet to an inch.



a. Clayey and Chalky Soil.
b. Chalk Marl and Chloritic Marl.
c. Upper Greensand } Sands with calcareous doggers.

Assuming the continuous layer of sandstone with *Am. rostratus* to be the speckled sandstone of Devizes and Lavington, the beds above are here about half their normal thickness.

Eastward up the Vale of Pewsey the best sections have been those afforded by the railway-cuttings. The original cuttings on the line between Savernake and Devizes were examined and described by Mr. T. Codrington in 1865;[1] and the fresh exposures made by the widening of these lines in 1898 have been carefully noted and measured by my colleague, Mr. F. J. Bennett. The following account of the principal cuttings has been compiled from the information obtained by both observers.

East of Stert the first cutting of any importance is that east of Woodborough Station. Of this Mr. Bennett remarks that it is a mile and a half long, but nowhere more than 10 feet deep; it traverses a low anticline the western slope of which very nearly coincides with the slope of the ground, and its axis is nearly north and south. In the middle of the cutting the beds seen are as follows:—

	Feet.
Greensand, weathering grey, mottled with rings and streaks of whitish marly sand, and including two thin layers of cherty siliceous stone enclosing glauconite grains, each about 3 inches thick - - - - - - -	7
Two layers of large doggers of whitish calcareous sandstone speckled with large grains of glauconite, sometimes merging into one layer - - - - -	2 to 2½
Greensand below.	

Pecten asper occurred frequently in and between the large doggers, which may possibly represent the "speckled rock" of Devizes.

Mr. Codrington says that the beds in this cutting seem to be from 20 to 30 feet below the base of the Chalk to the north. They yielded many sponges when the line was made, the lobed forms, such as *Hallirhoa costata* and *H. agariciformis*, being common here but rare at Savernake, while the forms which were common at Savernake were rare here. "Funnel-shaped sponges like *Chenendopora subplena*, Mich., and *Ch. expansa*, Ben., are common, some of them being as much as 18 inches across." He also obtained the following species from this cutting:—*Pecten asper*, *P. orbicularis*, *Exogyra conica*, *Holaster lævis* ?, and *Serpula* (*Vermicularia*) *concava*.

The cutting at New Mill (2 miles N.E. of Pewsey Church) yielded *Ostrea vesiculosa*, *Exogyra conica*, *Neithea quadricostata*, *Rhynchonella compressa* (=*convexa*, Sow.), teeth of *Lamna*, and pieces of coniferous wood (Codrington).

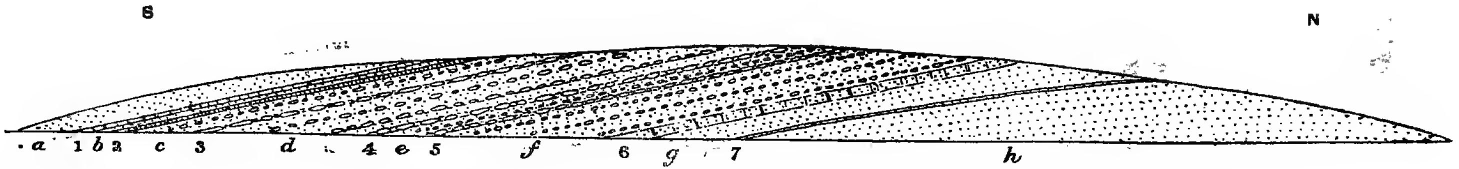
The cutting west of Savernake Station seems to have exposed lower beds, from which Mr. Codrington probably obtained *Nautilus elegans*, *Ammonites rostratus*, and some others of the list given by him and quoted below as from Savernake.

These beds must have dipped eastward beneath those exposed in the cutting east of the station which yielded many fossil

[1] "The Geology of the Berks and Hants Extension and Marlborough Railways." Mag. Wilts. Arch. and Nat. Hist. Soc., vol. ix., p. 167.

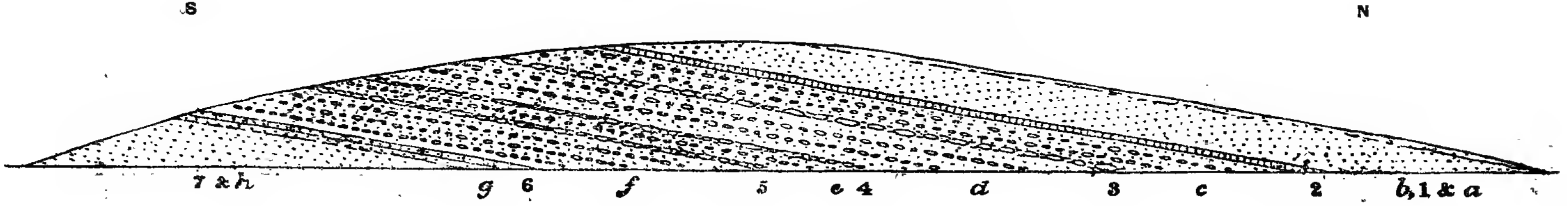
FIG. 72.—*Sections of the railway-cuttings north of Grafton, Wiltshire.* (F. J. BENNETT.)

A. View of the first or southern cutting.



a & *b*. Greenish sand with small lumps of bluish-grey chert.
1. Hard compact whitish sandstone.
2. Layer of bluish-grey chert.
c. Green sand with sandstone doggers.
3. Doggers, hard and softer sandstone, cherty in places.
d, 4, *e*. Yellowish greensand, mottled in places, with occasional doggers.
5. Course of hard sandstone doggers.
f. Greensand, ferruginous and mottled.
6. Doggers of hard compact stone.
g. Dark greensand, mottled.
7. Soft mottled sandstone (hardened bed *h*).
h. Fine greenish-grey sand.

B. View of the second or northern cutting.



sponges belonging to the genera *Chenendopora*, *Polypothecia*, and *Jerea*, with a few specimens of *Siphonia pyriformis* (= *tulipa*) and *Hallirhoa costata*." The sponges seemed to be most plentiful at from 25 to 30 feet below the top of the Upper Greensand, and to the westward of the station very few occurred." (Codrington.)

Mr. W. Cunnington informs me that the sponges from this cutting included the rare *Carterella cylindrica*, and that *Pachypoterion robustum* abounded in great variety of form.

The line from Savernake to Andover runs across the eastern end of the Pewsey anticline, and new cuttings for a second line of rails were made in 1898. These were examined by Mr. Bennett, who contributes the following particulars and the sketches for Fig. 72, the fossils found being sent to me for determination.

The first cutting north of Grafton shows a series of beds dipping southward, the highest of which cannot be many feet below the Chloritic Marl. At the southern end the dip is about $2\frac{1}{2}°$ to the south, but this decreases northward till at the northern end the beds are nearly horizontal (see Fig. 72). In the next cutting the same beds are seen again, but they dip to the north at about 3°. The thickness of the beds changes somewhat in passing from one cutting to another, and they may be correlated as follows:—

	1st Cutting.	2nd Cutting.
	Feet.	*Feet.*
a. Greenish-grey sand with small lumps of chert; *Pecten asper*, *P. orbicularis*, *Lima semisulcata*, *Hamites simplex*, and *Ammonites* (fragment like *splendens*)	4	
1. Whitish calcareous sandstone with little glauconite; *Avicula gryphæoides*, *Pecten* (*Neithea*) 5-*costatus*, and *Discoidea subuculus* -	1	8
b. Greyish sand with *Pecten asper* and *Discoidea subuculus* - -	1	
2. Layer of dull grey chert, compact, opaque, with *Avicula gryphæoides* and *Pecten asper*	1	1
c. Greensand with doggers of sandstone; *P. asper*	? 3	6
3. Doggers of hard greenish-grey sandstone and some chert - -	1	1
d, 4, & *e.* Yellowish-grey glauconitic sand with three layers of sandstone doggers; *Serpula concava*	$7\frac{1}{2}$	8
5. Course of hard sandstone doggers - -	$1\frac{1}{4}$	1
f. Yellowish-grey sand with ferruginous nodules	2	3
6. Doggers of compact cherty stone -	1	1
g. Fine greenish-grey sand mottled with lighter streaks and patches, a few small phosphatic nodules -	9	8
7. Soft mottled sandstone, *Avicula gryphæoides* and *Pecten orbicularis* - -	2	1
h. Fine greenish-grey sand, mottled as above. *Ammonites rostratus* -	4	1
	$37\frac{3}{4}$	39

The three lowest beds, *g*, 7, and *h*, may certainly be regarded as belonging to the zone of *Ammonites rostratus*, but where the top of this zone should be placed is doubtful.

The following is a list of the fossils found by Mr. Codrington in the Greensand of Pewsey and Savernake, with some corrections of his nomenclature. The sponges are in the Devizes Museum, and for a list of them (in modern nomenclature) I am indebted to Mr. W. Cunnington:—

—	Savernake.	New Mill.	Milkhouse Water and Pewsey.	Wood-borough.
Orbitolina concava	x	–	x	x
Carterella cylindrica	x	–	–	–
Chenendopora Michelini	x	–	–	x
Doryderma Benettiæ	–	–	–	x
„ ramosum	–	–	–	x
Hallirhoa agariciformis	–	–	–	x
„ costata	x	–	–	x
Holodictyon capitatum	–	–	–	x
Pachypoterion compactum	–	–	–	x
„ robustum	x	–	–	–
Rhopalospongia gregaria	–	–	–	x
Siphonia tulipa	x	–	–	–
Serpula (Vermicularia) concava	x	–	x	x
Holaster planus [=lævis]	–	–	x	–
Discoidea subuculus	x	–	–	–
Terebratula biplicata	x	–	–	–
Rhynchonella compressa [convexa]	–	x	–	–
„ latissima [dimidiata]	x	–	–	–
„ Gibbsi [?Schlœnbachi]	x	–	–	–
Exogyra conica	–	x	–	x
Ostrea vesiculosa	–	x	–	–
„ carinata [=frons]	–	–	x	–
Lima Hoperi [=globosa]	x	–	–	–
„ dupiniana [=semisulcata]	x	–		–
Pecten asper	x	–	x	x
„ orbicularis	–	–	–	x
„ (Neithea) quadricostatus	–	x	x	–
Plicatula pectinoides	x	–	–	–
Cardium spheroideum	–	–	x	–
Pholas constricta	x	–	–	–
Radiolites Mortoni	–	–	x	–
Ammonites rostratus	x	–	–	–
„ Mantelli	x	–	–	–
„ varians	x	–	–	–
Nautilus elegans	x	–	–	–
„ simplex [? expansus]	x	–	x	–
Belemnites minimus	–	–	x	–
Turrilites tuberculatus	x	–	–	

CHAPTER XVIII.

GAULT AND UPPER GREENSAND (SELBORNIAN) IN NORTH WILTSHIRE AND BERKSHIRE.

General Description.

Northward from Devizes, the outcrop or basset surface of the Gault and Greensand passes to the east of Calne; thence it curves north-eastward, and passing to the south of Swindon it finally runs eastward through Berkshire. In North Wilts the breadth of ground occupied by the formation is small, but in Berkshire the beds increase in thickness and spread out over a much wider tract of ground.

A general description of the Gault and Greensand along this part of their outcrop was given in the Survey Memoirs on Sheets 34 and 13 of the old series of maps, but both of these are now out of print. The first to recognise the existence of Malmstone in Berkshire was Dr. G. J. Hinde in 1885.[1] The thickness of this Malmstone and of the other members of the succession between Didcot and Chilton was indicated by the present writer in 1889.[2]

The Lower Gault, which, near Devizes is about 90 feet thick, probably maintains that thickness through North Wiltshire, but on the borders of Berkshire the argillaceous beds begin to thicken, till in the east of that county borings at Wantage and Didcot proved them to be 220 feet thick. It by no means follows, however, that the whole of this depth is to be ascribed to the zones of *Ammonites interruptus* and *Am. lautus*, for a part of the increase is due to the incoming of silty marls below the Malmstone, and these more probably belong to the zone of *Ammonites rostratus*. Even when some 50 feet of such marl is deducted, there still remains 170 feet for the Lower Gault at Didcot, and its thickness is probably very little less in the western part of Berkshire.

The Malmstone is probably continuous as a thin band at the base of the micaceous sandstone through North Wilts, but is seldom seen because the escarpment of the sandstone is so steep that its foot is covered with talus and fallen debris; in many places landslips have taken place and large masses of the sandstone and overlying sand, with in some cases portions of Lower Chalk have fallen and slipped down on to the Gault, so that the actual face of the sand and sandstone is completely concealed, as indicated in Fig. 73.

Near Calne, the Malmstone and sandstone are together from 50 to 60 feet thick, but northward they seem for a certain

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[1] On beds of Sponge-remains in the Lower and Upper Greensand of the South of England. Phil. Trans. Roy. Soc., p. 416, 1885.

[2] The Geology of Upton and Chilton in Berks. Proc. Geol. Assoc., vol. xi., p. 198.

distance to get thinner, for below White Horse Hill they do not appear to be more than 35 feet. Thence, however, they thicken again to the eastward, and the sandy gaize becomes more and more of a malmstone till between Didcot and Wallingford there is a mass of calcareous malmstone which cannot be far short of 100 feet in depth.

With the exception of *Pecten orbicularis* and *Avicula gryphæoides* fossils are rarely met with in the Malmstone group along this tract of country.

North of Devizes there is a remarkably rapid diminution in the thickness of the glauconitic sands which form such a conspicuous part of the formation along the greater part of the Vale of Pewsey.

At Blacklands, only 4½ miles north of Devizes, there is not more than 10 feet of grey and green micaceous sand between the micaceous sandstone and the phosphatic base of the Chalk. No fossils were found in this sand, so that it is doubtful to what zone it belongs, but it is evident that this 10 feet is all that can represent the 60 feet of sands with layers of calcareous sandstone near Devizes, and it is more likely to belong to the zone of

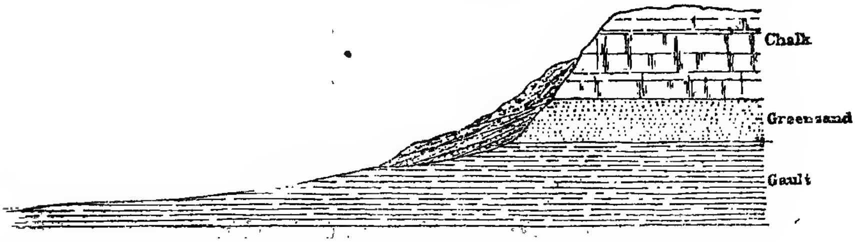

FIG. 73.—*A frequent aspect of the Chalk escarpment in N. Wiltshire.*

Am. rostratus than to the sands with *Pecten asper.* It would seem that the sands of the Vale of Pewsey form a long sand-bank, the greatest extension of which was from east to west, and that the bank slopes away and thins out to the northward.

Further to the north-east on approaching Berkshire, green sand sets in again above the malmstone, and they continue through that county with a thickness varying from 16 to 25 feet.

The following are comparative thicknesses of the several portions of the series at different points (see also Fig. 76):—

———	Calne.	Uffington.	Wantage.	Didcot.
	Feet.	*Feet.*	*Feet.*	*Feet.*
Soft green sand -	? 0 to 10	20	16	16
Sandstone and malmstone -	50 to 60	35	60	80
Soft grey silty marl -	? 10	50	50	50
Grey micaceous clays -	90	140	170	170
	160	245	296	316

Stratigraphical Details.

Lower Gault.

The lower part of this (zone of *Amm. interruptus*) consists of laminated silty and micaceous clays, grey lilac and yellow, weathering yellowish, and containing lumps of argillaceous ironstone. These beds are exposed in the brickyard at Uffington and in the railway cutting near the station, but no fossils were observed in them.

The sandy nature of these clays and the fact of their weathering yellow render it possible to trace the base of the Gault along the tract between Balking and Denchworth, where it rests on the Kimeridge Clay. They can also be seen in the railway-cuttings by Challow.

Similar beds are exposed in the well-known brickyard at Culham, in Oxfordshire; the section at the eastern end of the pit, when seen by me in 1887, being as follows :—

		Feet.
Gault	Light grey laminated clays, with a thin layer of yellow clay, very micaceous in the lower part (*Amm. interruptus*, &c.) -	16
	Hard sandy clay, full of small quartz pebbles, with a few phosphatic nodules -	2
Kim. Clay	Bright brown calcareous and sandy ironstone, about	$0\frac{1}{2}$
	Dark clay - - - - -	16

Fig. 74.—*Section at Culham, Oxfordshire.*

4. Gravel.
3. Gault.
2. Lower Greensand.
1. Kimeridge Clay.

The Lower Greensand should have been drawn as thinning out more in the middle of the section.

As the ironstone does not contain pebbles it is probably a bed in the Kimeridge clay, altered by contact with the Lower Greensand, which is here cut out by the Gault. The sands were formerly dug by the main road above the old kiln and coarse brown quartz-sand, with large blocks of whitish sandstone can still be seen in the cottage gardens.

A manuscript account of this section by Daniel Sharpe, written about 1852, has been placed in my hands, and he states that at the west end of the brickyard the Gault "rests on a mass of coarse yellow brown sand, surmounted by a bed of coarse sandstone about 9 inches thick." He was informed that this sand thinned out gradually to the eastward, and his account of the east end of the section agrees with that above given

moreover, he found *Thracia depressa* in the ferruginous stone at the top of the Kimeridge Clay.

Professor Phillips[1] has recorded the following fossils from this locality:—

Ammonites dentatus (= interruptus)	Inoceramus concentricus, *Sow.*
" lautus, *Sow.*	Nucula pectinata, *Sow.*
Belemnites minimus, *Lister.*	Pecten quinquecostatus, *Sow.*
Dentalium decussatum, *Sow.*	Plicatula pectinoides, *Sow.*
Rostellaria sp.	Cyclocyathus Fittoni, *M. Edw.*
Solarium conoideum, *Sow.*	Balanus sp.

The higher part of the Lower Gault, as seen in a brickyard at Ardington Wick, near Wantage, is a stiff grey marly clay with glauconite grains, small phosphatic nodules, and a few *Belemnites minimus.*

Upper Gault and Malmstone Group.

Zone of Ammonites rostratus.

Where this zone or *assise* is fully developed in Berkshire it consists of the following members:—

	Feet.
3. Grey marl with large grains of glauconite - -	10 to 12
2. Sandy marls and malmstones - - - -	60 „ 90
1. Light-grey silty marls passing down into darker grey marl - - - - - - - -	50 „ 60

As No. 1 has been mapped by the Geological Survey with the Gault, it will be convenient to mention the chief exposures of this before dealing with the upper beds which form the mass of what is grouped as Upper Greensand.

Near Glebe Farm, south of Uffington, below the line taken as the base of the Malmstone, whitish silty marl can be seen in the ditches, and I was informed that the well at Glebe Farm had been dug for 38 feet through such marl, finding water at that depth in a band of soft stone.

Similar marls can be seen below the Malmstone in road-cuttings near Wantage, Didcot, and Steventon, and they sometimes contain layers of impure malmstone.

Lower beds are exposed in the railway-cutting north of Didcot, the lowest bed seen being a micaceous marly clay containing scattered phosphate nodules and many specimens of *Avicula gryphœoides,* a fossil which is common in Upper Gault and in Malmstone, but never found in the Lower Gault. The highest beds seen in this cutting are soft grey shaly micaceous marls, which probably pass up into the whitish silty marl above mentioned.

The highest part of the Gault, sandy clays and marls, is seen at the north-west end of the cutting on the Great Western line near North Moreton (see p. 271), and in the road-cutting south of Little Wittenham.

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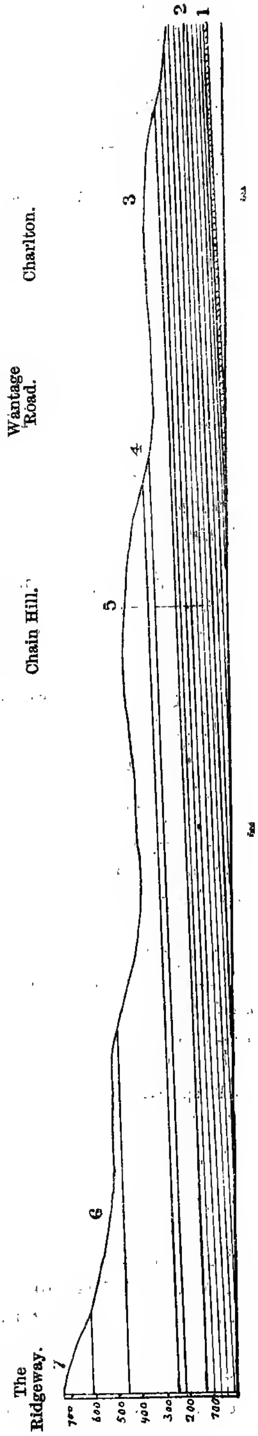
[1] Quart. Journ. Geol. Soc., vol. xvi., p. 309.

FIG. 75.—*Section through Chain Hill and Charlton, east of Wantage.*

Horizontal scale two inches to a mile. Vertical scale 800 feet to an inch.



7. Upper Chalk.
6. Middle Chalk 150 feet.
5. Lower Chalk 220 feet.

4. Green sand } Selbornian about 300 feet.
3. Malmstone }
2. Gault.
1. Lower Greensand.

There is a gradual passage from the Upper Gault marls to the beds which have been mapped as Upper Greensand, and the line drawn between them does not coincide with any special horizon.

In North Wiltshire there are few good sections of these beds.

At Blackland, near Calne, a cutting on the road to Devizes shows the following succession:—

		Feet.
Chloritic marl with many fossils		$2\frac{1}{2}$
Dark-green glauconitic sand, rather coarse and hard, with some nests of micaceous sand, penetrated from above by pipes of glauconitic marl; passes into the next		1
Grey glauconitic sand, becoming more and more micaceous below		10
Soft buff micaceous sandstone	seen for	20

Near the bottom of the hill a stiff grey sandy marl was exposed.[1]

On approaching Berkshire the sandstone or gaize becomes less sandy and passes into malmstone, while bands of silty marl make their appearance between the beds of malm. Some of the stone is purely siliceous and some partly calcareous, the two varieties being generally distinguishable by the weight of a sample in the hand, the calcareous stone being much heavier than one which consists largely of organic silica.

At the spring-heads, called "the Coombes," south-west of Kingstone Lisle, calcareous malmstone is seen in the watercourse, and in the bank above there is grey marl overlain by friable siliceous stone containing much organic silica.

At Challow there is hard micaceous marl passing up into micaceous malmstone, above which, or in which, are several feet of hard grey calcareous ragstone.

Near Wantage there must be a thickness of 60 or 70 feet between the lowest stone-beds and the soft green sand which forms the summit of the division, but this is not wholly occupied by stone, the higher part consisting of micaceous marl and grey marly clay with grains of glauconite. These beds are only seen in ditches, but are important, because, if the malmstone were absent, they would be regarded as Gault marls, so that the malmstone here may be described as occurring in the midst of the marls of the Upper Gault.

Westward, the stone-beds increase rapidly in thickness, and form a broad plateau by Ardington, Hendred, Harwell, Didcot, Hagbourne, North Moreton, and Brightwell, near Wallingford. Good sections can be seen in the cuttings of the Didcot and Newbury line, of the Great Western line near North Moreton, and in the road-cutting a mile and a half north of Wallingford. It is along this tract that the malmstone attains its greatest thickness, probably about 90 feet; the stone lies in regular beds, the central part being a fairly pure malmstone, containing sponge spicules and globular colloid silica in large quantity, and weathering to a very light grey, so that it might easily be mistaken for grey Chalk on a cursory inspection.

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[1] *See* also Proc. Geol. Assoc., vol. xiv., p. 346.

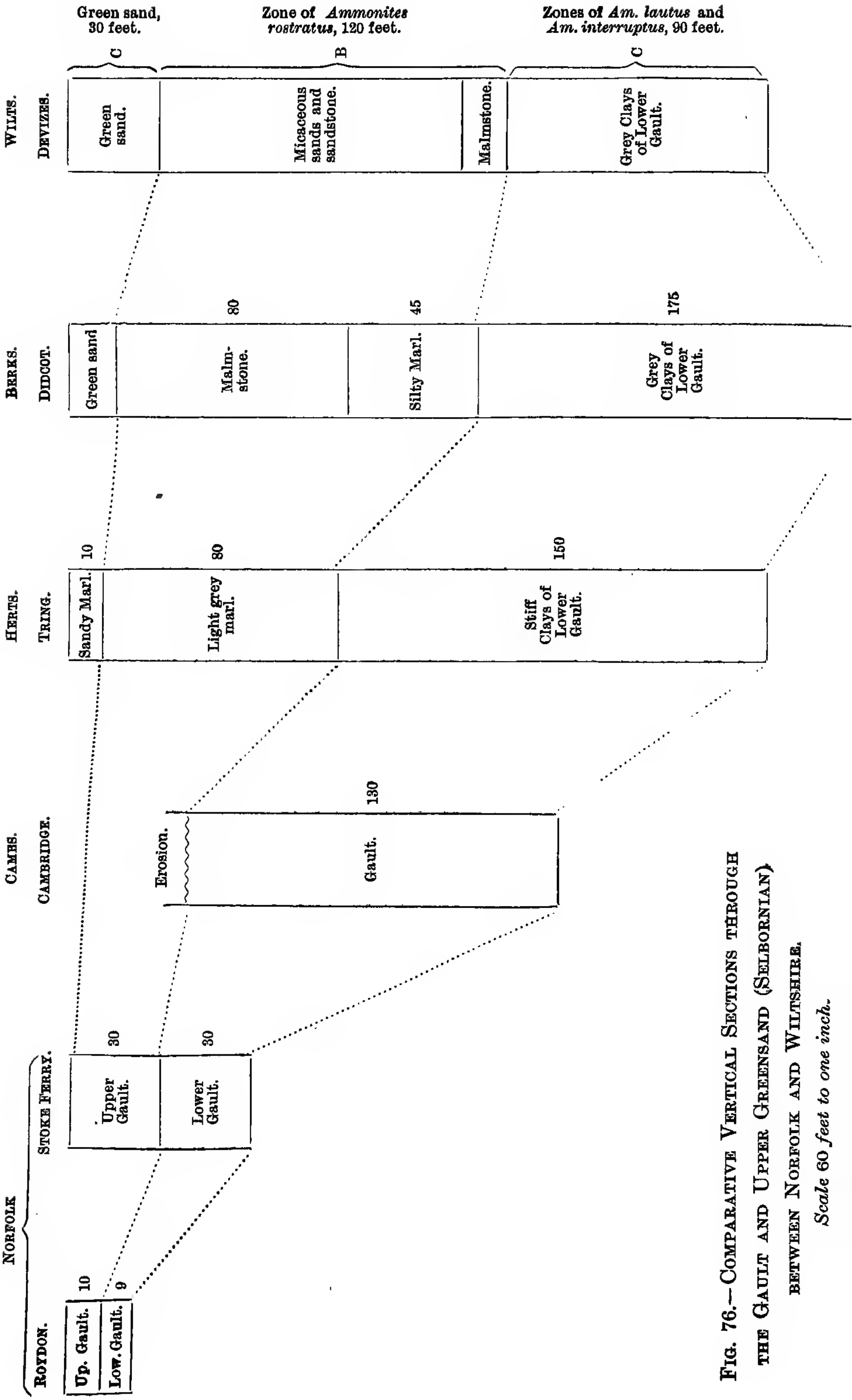


FIG. 76.—COMPARATIVE VERTICAL SECTIONS THROUGH THE GAULT AND UPPER GREENSAND (SELBORNIAN) BETWEEN NORFOLK AND WILTSHIRE.

Scale 60 feet to one inch.

One of the best sections is that in the cutting on the Great Western line between North and South Moreton. At the north-west end of the cutting there is dark sandy clay (Upper Gault) like that at Didcot (see p. 269), succeeded by grey sandy marl which passes up into soft light grey malm with bands of hard calcareous malmstone; these beds occupy a syncline, at the base of which a nearly black sandy marl is seen, apparently replacing the upper part of the grey marl. The beds then rise to the south-east, and the first bridge passes over the centre of a low anticlinal curve, this being well marked by a bed of hard siliceous stone which has a yellowish staining. South-east of this bridge there is a second syncline, and then a rolling dip to the S.E., which brings in higher beds of light grey siliceous stone near the second bridge.

The highest beds of this division are found in the cart-road leading up the hill north of Satwell; the exposure is obscure, but tough grey marl passing up into similar marl containing grains of glauconite can be seen.

Green Sand.

As stated on p. 267, at Calstone and Cherhill, near Calne, there is nothing which can be recognised as the equivalent of the Warminster Greensand, the soft grey sand which overlies the malmstone being micaceous almost to the top, and destitute of fossils. Near Wroughton, however, a soft green glauconitic sand without mica sets in, which may be regarded as belonging to the zone of *Pecten asper*. Mr. F. J. Bennett informs me that this green sand is visible in the dingle at Bincknoll, south-west of Swindon, and more clearly in the railway-cutting at Chiseldon, where some 15 feet of it are seen below the Chloritic Marl.

In Berkshire, this sand is seen in the cutting on the main road, east of Woolstone Springs, and here the green and grey sands together must be from 20 to 25 feet thick.

By the side of the same road south of Westcott there is a small sand-pit showing the following section:—

	Feet.
4. Chalk Marl without visible green grains - -	3
3. Hard Chalk Marl with scattered green grains - -	2
2. Green glauconitic marl with a few phosphatic nodules and fossils - - - - - -	$2\frac{1}{2}$
1. Dark green sand -	$3\frac{1}{2}$
	11

Each part of the above succession passes into the next so that there is here a complete passage from Greensand to Chalk.

A pit in the deep road-cutting south of Childrey exposes from 18 to 20 feet of these beds, the upper part consisting of greenish glauconitic marl with a layer of ferruginous nodules about 8 feet down, and the lower part of dark green sand, marly at first, but passing down into sharp sand consisting only of quartz and

glauconite. Another pit at East Challow shows a similar section, the marly sand being mottled with streaks and pipes of marly or chalky matter. It is a question whether this marly material was an original constituent or whether it had been unfiltrated from the Chalk above.

The same succession can be seen by the cottage called the Ark, south of Wantage, and when an excavation for the Waterworks was made here in 1877, Mr. E. C. Davey[1] found many fossils in what he regarded as Greensand, but they probably came from the Chloritic marl or phosphate-bed; they included *Pecten asper*, *Ammonites varians*, *Am. rotomagensis*, *Avellana cassis*, *Pleurotomaria*, &c.

Similar Greensand can be seen north of Lockinge, in the lane 200 yards east of West Hendred church, and in the shallow cutting on the Great Western Railway between Cholsey and South Moreton.

[1] *See* Catalogue of Fossils from the Cretaceous Beds of Berkshire. 8vo. Wantage, 1877, pp. 11, &c.

CHAPTER XIX.

GAULT AND UPPER GREENSAND (SELBORNIAN) IN OXFORDSHIRE AND BUCKINGHAMSHIRE.

General Description.

No adequate description of the Gault and Greensand of these counties has yet been published. A very short account was given by Prof. Hull in the Geological Survey Memoir on Sheet 13 (published in 1861 and now out of print), and a description of that part of the outcrop coming within the limits of Sheet 7 was contributed by the present writer to Mr. Whitaker's Memoir on the Geology of London (1889).

In their passage through these counties the clays which are known as the Gault develop a greater thickness than in any other district except that of Sussex. A well-boring at Shillingford, north of Wallingford, traversed a depth of 144 feet of Gault and from the height of the top of the clay near by it has been calculated that the full thickness of the Gault, including both Lower and Upper Gault, must be here about 190 feet. The thickness becomes greater to the northward for a boring at Thame Park is said to have traversed 200 feet of Gault, and borings near Tring have proved a thickness of 230 feet of Gault; of this 150 feet is believed to belong to the Lower Gault and 80 feet to the Upper Gault, but the relative thicknesses in Oxfordshire have not been ascertained.

Phosphatic nodules have been worked at two horizons, one at 20 or 30 feet from the base of the Gault, and a second at 150 feet from the base in a seam of green sand which is taken as the base of the Upper Gault.

The Lower Gault presents some anomalies in its fossil contents, for the lower nodule-bed has yielded species which in the south-east of England occur only in Upper Gault, such as *Ammonites rostratus, Am. varicosus, Am. cristatus, Inoceramus sulcatus,* and *Terebratula biplicata* in association with *Am. lautus, Am ochetonotus, Am. splendens,* and *Am. tuberculatus.*

The Upper Gault, which really forms the lower part of the zone of *Ammonites rostratus,* becomes more and more calcareous as it is followed to the north-west. In Buckinghamshire the greater part of it is so marly and so light coloured that it might be mistaken for Chalk Marl, but it passes up into a sandy micaceous marl. Water is frequently thrown out at the junction of these marls with the overlying malmstone, and in Oxfordshire a succession of fine springs occur at this horizon.

The Malmstone of Oxfordshire is a continuation of that of Berkshire. Much of it is calcareous, but some beds are purely siliceous and consequently of light specific gravity. *Ammonites auritus* and *Avicula gryphæoides* occur rarely. In the west of the county it is probably about 80 feet thick, but it gradually thins to the westward; near Chinnor it has thinned to 30 or 35 feet, and in Bucks it thins out altogether, passing first into the condition of silty micaceous marl enclosing layers and nodules of calcareous stone, and finally into similar marl without any stone. In its final state it has been mapped as Gault, and it is difficult to say how much of the Upper Gault near Tring may be the actual equivalent of the Malmstone.

The thin band of "Greensand" which has been traced through Berkshire, is continuous through Oxfordshire, but does not seem to exceed 12 feet in thickness. It has also been traced into Bucks as far as Tring (which town is in a projecting part of Hertfordshire), but seems to die out for a space near Ivinghoe. No fossils have been found in it.

So far as can be ascertained from exposures and from borings, the succession between Thame and Chinnor may be compared with that near Tring in the following manner:—

Feet.	*Chinnor.*	*Tring.*	*Feet.*
12	Soft green sand.	Soft greenish silt - -	6
12	Grey marl with glauconite grains.	Sandy micaceous marls	20
30	Malmstone with layers of marl.		
80	Marly clays.	Marly clays - - -	60
150	Dark grey and blue clays.	Grey and blue clays - -	150
284			236

STRATIGRAPHICAL DETAILS.

Lower Gault.

OXFORDSHIRE.—The section exposed at Culham has already been described. The lowest part of the Gault is exposed in two brickyards near Thame. In 1885 the pit south-east of Thame showed about 20 feet of dark grey micaceous clay, containing a few scattered phosphatic nodules, but the only fossils seen were fragments of *Inoceramus concentricus*. The foreman stated that a boring proved another 20 feet of dark tough clay at the base of which is a thin layer of shaly rock, and below this sand from which water rose up 17 feet.

South of Thame, by the road to Tetsworth, is another brick-yard, dug partly in Lower Cretaceous clay, but also exposing Gault at the western end, and from this I obtained fragments of *Ammonites interruptus* and *Belemnites minimus*.

At Crendon, north of Thame, there is an outlier of Gault, and

a quarry worked for stone on the east side of road exposed the following succession in 1885:—

		Feet.
Gault.	Clayey soil passing down into tough grey clay, slightly micaceous, and showing layers of darker and lighter grey; impressions of *Inoceramus* - - -	10 to 12
Lower Greensand.	Brown ferruginous sandstone with small pebbles of quartz and lydianite; in places are lumps of calcareous stone -	1 to $1\frac{1}{2}$
	Thin layer of laminated grey and yellow clay; laminated clays with large lenticular concretions of heavy purple ironstone -	$2\frac{1}{2}$
Purbeck and Portland Beds, seen for - - -		16

BUCKS.—The layer of phosphatic nodules in the lower part of the Gault was worked between the years 1875 and 1884, at Towersey, near Thame, and between the hamlets of Ford and Moreton, further east. The late Mr. W. Keeping, F.G.S., saw the workings near Ford in 1876, and communicated the following notes to me:[1]—

"The coprolite seam is 3 or 4 inches thick, and is constant throughout the pit, though the bed is irregular in position. The irregularity is of two kinds, the commonest being slips of a few inches (4 to 10), cutting off the seam with a clear face marked by slickensides; in other cases the bed is bent downwards to a similar extent, and this bending is due, I am inclined to think, to subsequent folding and not to irregularity of deposition.

"The matrix of the seam is a stiff calcareous clay crowded with phosphatised shells and lumps of 'coprolite,' which, in my cursory search, I could not prove to have suffered from erosion previous to being embedded in the Gault, while some of them, such as *Hamites*, were in such a condition that they could not have sustained much knocking about on a shore."

He also remarked that though the nodules were similar to those of the Cambridge Greensand, they differed in being larger, harder, and in the rarity of tubular forms; further, that the fossils differed greatly, some not known or very rare at Cambridge, such as *Inoceramus sulcatus*, being here very common, while others common at Cambridge were here absent or rare. "Above the [nodule] bed comes a hard clay with iron-stained joint-planes, which is covered by a true clay, somewhat lighter coloured than ordinary Gault, and containing a second irregular coprolite zone in a series of lenticular patches. Its nodules are smaller than in the regular seam below."

When I visited the district in 1885 no pits were being worked, but I found trenches and works only recently abandoned near Marshall Farm south of Bishopstone. I collected some fossils, and found that Mr. Hayter, then schoolmaster at Monks Risborough, had collected many while the works were in progress. The information I obtained and the aspect of the nodules confirm

[1] These notes were afterwards handed to Mr. F. G. H. Price, F.G.S., who published them in his "Memoir on the Gault." London, 1879.

Mr. Keeping's account. The following is a combined list of the species obtained by Mr. Keeping, Mr. Hayter, and myself, and it will be seen to be a curious assemblage for Lower Gault:—

Ichthyosaurus campylodon.	Aporrhais marginata.
Plesiosaurus sp. (teeth.)	Dentalium decussatum.
Ischyodus sp.	Natica Genti.
Protosphyræna ferox.	Solarium conoideum.
Lamna appendiculata.	„ ornatum.
Oxyrhina macrorhiza.	Pleurotomaria itieriana ?
Nautilus clementinus.	„ Rhodani.
*Belemnites minimus.	„ sp.
Ammonites auritus.	Exogyra rauliniana.
„ cristatus.	Hinnites (new sp.)
„ lautus.	Plicatula pectinoides (rare).
„ ochetonotus.	„ sigillina.
* „ rostratus.	Cardita tenuicosta.
„ splendens.	*Inoceramus sulcatus.
„ tuberculatus.	„ tenuis ?
* „ varicosus.	Pholadomya decussata.
Baculites Gaudini ?	Terebratula biplicata.
Hamites intermedius.	Trochocyathus conulus.
Aporrhais carinata.	„ harveyanus.

Those to which * is prefixed are common fossils.

The same bed crops out in the ditch by the side of the main road 1½ miles E.S.E. of Aylesbury, and from it I obtained fragments of *Ammonites Beudanti*, *Am. tuberculatus*, *Am. varicosus* and *Hamites*, with *Belemnites minimus*, *Solarium*, and *Inoceramus sulcatus*.

There is a brickyard in Gault at Rushmead, north of Rowsham, but I saw no fossils or phosphates in the clay there. Thence the Gault spreads upwards on to the high ground near Wing, and a brickyard at Littleworth has exposed interesting sections of the basal beds of the formation. The late Prof. Green saw a clear section on the southern side of the excavations about 1860, and noted the succession as follows:—

		Feet.
Drift.	Sand and pebbly sand - - - -	14
Gault	Pale blue laminated clay with whity-brown phosphatic nodules -	15
	Yellow earthy concretionary limestone, with much ochre, pyrites, some carbonate of copper and brown phosphatic nodules	1½ to 2
Kimeridge.	Stiff bluish-black clay with large septaria	6

When I visited the place in 1884 this section was obscured, but a cut on the north side showed Kimeridge Clay passing beneath Gault without any stone-bed, and only a thin parting of brown ferruginous matter. The Gault contained *Ammonites interruptus*, *Am. lautus* and *Bel. minimus*. In the little stream, however, which runs through the yard I found blocks of the stone described by Prof. Green, a hard calcareous ironstone full of phosphate nodules, and containing many small Terebratulæ, which were identified by Mr. Etheridge as *Waldheimia tamarindus*, a Lower Cretaceous form which however has been found occasionally in the Gault.

A boring was made by the Grand Junction Canal Company in 1855 at Slapton Lock, three miles south of Leighton Buzzard, and samples are preserved in the offices of the Company at Marsworth, which furnish the following particulars:—

Gault clay to 46 feet
Phosphate nodules and fossils at 61 feet.
Clay with *Inoceramus* at 66 feet.
Clay down to 71 feet.
Sands from 72 to 86 feet.

It would appear that there is a nodule-bed about 10 feet from the base of the Gault; among the fossils preserved I identified the following, *Ammonites interruptus, Am. cristatus, Am. rostratus, Am. varicosus ?, Inoceramus sulcatus, Inoc. concentricus, Inoc. tenuis ?.*

Other borings were made by the Canal Company at Lock 33 Ivinghoe, at Lock 38 Marsworth, and at Bulbourn, both of the latter traversing the whole thickness of the Gault, which according to the records preserved was in one case 248 and in the other 238 feet thick. Another boring was made at Gubblecote, west of Marsworth, in 1885 (*see* p. 282). The samples obtained from these borings show that much of the Lower Gault is of a light-grey colour, and is more or less calcareous; samples only 28 and 29 feet from the base at Gubblecote were examined by Mr. W. Hill, who describes the material as a very calcareous clay or marl. Thus both the Lower and Upper Gault show a tendency to become more calcareous as they are followed to the northward.

Upper Gault and Upper Greensand (Malmstone).

Zone of *Ammonites rostratus.*

OXFORDSHIRE.—On the eastern side of the Thames Valley the malmstone emerges from beneath the plain of river gravel near the village of Roake, and forms a well-marked ridge which runs thence to the north-east. It was from the soft malm or from the underlying marl at Roake that the specimen of *Hamites armatus* figured by Sowerby was obtained The stone has been dug half a mile N.E. of the village, and again in a larger pit to the northward by Hollantide Bottom.

From these pits the following fossils were obtained:—

Ammonites auritus.	Ostrea sp.
Aporrhais Parkinsoni.	Pecten orbicularis.
Cucullæa carinata.	Echinospatagus sp.

One of the best sections of this division is in the road-cutting down Clare Hill, 2½ miles N.N.W. of Watlington. At the top near the guide posts a tough calcareous marl with a few scattered grains of glauconite is seen in the bank, on the slope to the north firm grey malmstone crops out, and about 40 feet of it

is seen. Opposite the bench mark of 330 feet a layer of malmstone overlies a foot or two of softer micaceous marl, and still lower a water-hole showed grey micaceous marl with crushed *Ammonites auritus*. This is probably the top of the Gault marls, but belongs to the zone of *Am. rostratus.*

Pecten orbicularis and *Avicula gryphæoides* were found in siliceous malmstone near Clare South Farm, and grey marls with a 3 feet course of malmstone are exposed in a pit east of Wheatfield Church.

Beyond Adwell, where two strong springs issue from the rock, the ridge becomes less marked; at Chinnor, half a mile N.W. of the church, a well had been recently sunk in 1885, and I was informed that the beds traversed were:—

	Feet.
Soft grey marl - - - - - - -	10
Ragstone in irregular beds, separated by layers of grey marl, the lowest being a bed of rock with water -	27

Among the material brought up from the shaft were many blocks of the rocky beds, a sandy malmstone with nodular lumps in which colloid silica was more abundant than in the rest of the rock; these blocks yielded *Ammonites auritus* (var. *catillus*), *Am. planulatus*, and *Avicula gryphæoides.*

BUCKS.—The malmstone with some beds of firm fissile sandy marl is traversed by the railway-cuttings near Risborough station, its dip varying from 2° to 7°, and again in the railway-cutting south of Kimble station. The thickness of actual stone near Kimble is not more than 15 or 16 feet; near Turville it seems to pass into sandy marl with lumps of calcareous stone.

At Buckland the following succession can be made out along the road from south-east to north-west (*see* Fig. 77):—

Soft dark-green sand.
Soft grey shaly and sandy marl.
Dark-grey micaceous marl passing down into greenish sandy marl, with lumps of hard marlstone containing many *Avicula gryphæoides.*
Dark-grey laminated marl with *Avicula gryphæoides* passing down to bluish silty clay.

The total thickness is probably not more than 12 or 14 feet.

Going northward along this road we come to Puttenham, where phosphates were dug in 1874 from the seam at the base of the Upper Gault, and the following account is quoted from notes taken in that year.[1] The section here shown was:—

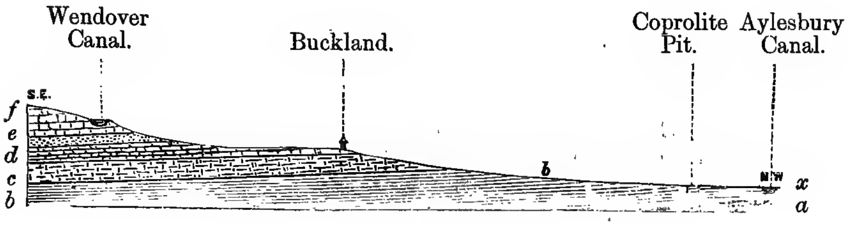
	Feet.
Whitish marly clay looking very like Chalk Marl but containing much "race" and a few light-coloured phosphatic nodules	8
Coprolite-bed, the upper part a grey, sandy clay with green grains and some nodules; the lower part a stiff dark greensand full of rolled black nodules	1½
Stiff blue-black clay at the bottom of trench.	

[1] See "Relations of the Cambridge Gault and Greensand," Quart. Journ. Geol. Soc., vol. xxxi., p. 265.

From the upper part of the coprolite bed I extracted the following fossils in an unphosphatised condition—*Plicatula pectinoides, Avicula gryphæoides, Pecten orbicularis, Lima globosa,* and *Ammonites rostratus.*

"On the [washed] heap there was a paucity of fossils, with the exception of *Plicatula pectinoides,* which was common. The smaller nodules were very like those of Cambridge, but the larger ones presented a curious appearance, being evidently

FIG. 77.—*Section through Buckland near Aylesbury.*[1]



f Chalk marl.
e Dark green sand.
d Flaggy calcareous sandstone with marly bands.

c Bluish sandy clay.
b Whitish marly clay.
x Sandy marl, coprolite bed.
a Stiff dark Gault.
} Upper Gault.

phosphatic septarian stones, hollow in the middle and split up by contraction-cracks, which contained carbonate of lime. When struck they fell into numerous small cubical pieces. These nodules were a difficulty to me at first (as being different from any found at Cambridge), until I had broken up several and saw that the *débris* were exactly like the little angular fragments so common in the Cambridge Bed and often bearing small *Plicatulæ* and *Ostreæ* A very little rolling would suffice to break up these hollow nodules; and thus the apparent absence of these forms in Cambridgeshire is satisfactorily explained while the quantity of 'coprolite' *débris* there existing is likewise accounted for.

"On the other side of the canal near the village of Puttenham another pit has been opened (1874) showing the same succession." Here I obtained many fossils from the heap of washed nodules and Dr. Barrois subsequently collected a still larger number. The following list includes the species thus found, the letter J indicating those found by myself only, and the letter B by Dr. Barrois and not by me:—

[1] Quart. Journ. Geol. Soc., vol. xxxi., p. 265.

Ichthyosaurus campylodon.
Lamna appendiculata.
J. Protosphyræna ferox.
Ammonites auritus.
B. „ interruptus ?.
„ mayorianus.
„ raulinianus.
„ rostratus.
B. „ „ var candolleanus.
„ splendens.
J. „ „ var cratus.
B. „ Studeri ?.
B. Hamites desorianus.
B. „ intermedius.
Belemnites minimus.
B. Nautilus clementinus.
B. Dentalium decussatum.
B. Pleurotomaria Rhodani.
Solarium ornatum.
Avicula gryphæoides.
B. Exogyra rauliniana.
J. Lima parallela.
Plicatula pectinoides.
„ sigillina.
J. Hinnites trilinearis.
B. Ostrea pectinata (? frons).
Spondylus gibbosus.
Terebratula biplicata.
J. Serpula articulata.
B. Cidaris gaultina.
B. Pentacrinus Fittoni.
Trochocyathus angulatus.
B. „ harveyanus.
J. Coscinopora quincuncialis.

The same seam of phosphatic nodules was also worked at Cheddington and at Slapton to the north-east; a boring made to supply the Cheddington works with water passed through 150 feet of Gault before reaching the sands below.

In 1885 a trial-boring for water was made at Gubblecote, at a spot one mile E.S.E. of Long Marston Church, and this was watched by Mr. A. M. Brown, of Tring, who took a series of samples, which were afterwards submitted to Mr. W. Hill (*see* Chapter xxiv.). This boring passed through the whole of the Gault, and the particulars were as follows:—

		Feet.
Upper Gault 70 feet.	Soft blue sandy micaceous marl	13
	Hard bluish sandy micaceous marl	30
	Grey silty and marly clay	26½
	Layer of phosphate nodules in glauconitic marly sand	0½
Lower Gault 145	Dark-blue clay with ferruginous stains	50
	Blue clay with lighter-coloured layers	31
	Light-grey clay with a band of dark-blue clay about 11 feet thick	35
	Light-grey calcareous clay, with a thin seam of hard rock (? limestone)	1½
	Layer of phosphatic nodules	0½
	Dark brownish clay, becoming sandy and glauconitic below	22
	Blue sandy clay with phosphatic nodules at the base	3
	Hard grey clay with much quartz sand	2
Lower Greensand	Hard coarse sand mixed with clay	8
	Coarse white sand with water	2½

Upper Greensand (Glauconitic Sand).

The soft green sand which has been traced through Berkshire (see p. 273) is known to run through Oxfordshire and for some distance into Buckinghamshire, but it is not often exposed, because it is only a thin band and never more than 10 or 12 feet thick.

In its course through Oxfordshire it was only seen in small exposures either in ditches or in roadside banks. There is an

[1] Recherches sur le Terr. Cret. Supérieur (1876), p. 150.

outlier of it on Clare Hill, north of Watlington, and another south of Wheatfield. The following note is from a manuscript left by the late Sir Joseph Prestwich, and was written in 1850. It is headed Easington, and probably refers to the road-cutting a little south-east of that village, where part of it can still be seen:—

	Feet.
Very dark pure greensand - - - -	10
Malm rock, grey drying white, [partly a] clayey calcareous rock, upper beds fissile - - about	70
Gault, bluish brown.	

In Bucks there are some better exposures; it is traversed by the railway-cutting north-west of Monks Risborough, the succession at the N.E. end of the cutting being:—

Greenish glauconitic marl.
Dark green glauconitic sand, fine grained.
Greenish-grey sand with layers of calcareous stone.

The passage from Chalk Marl down into the Greensand can be seen in the bank by the roadside north-east of Bushey Leys. No fossils or phosphate nodules occur here or elsewhere in Bucks at the junction, so that one cannot say where the Greensand ends and Chalk begins.

In Aston Clinton Park a trench made in 1885 near the house showed about 6 feet of bright green sand passing up through glauconitic marl into Chalk Marl, the total depth seen being about 12 feet.

Its existence at Buckland has been mentioned on p. 280. Thence it has been traced through the low ground north of Tring, and it was traversed by borings made for the Grand Junction Canal Company at Marsworth and Bulbourne. Its thickness here, however, is only about six feet, and north-east of Ivinghoe it seems to thin out entirely, though it sets in again near Eddlesborough in Bedfordshire (see p. 287).

CHAPTER XX.

GAULT AND UPPER GREENSAND (SELBORNIAN) IN BEDFORDSHIRE AND CAMBRIDGESHIRE.

General Remarks.

The Gault of these counties is only in part a continuation of that of Buckinghamshire, for it is only the Lower Gault which is continuous. The Upper Gault is traceable for a certain distance, but thins out as if by erosion in the district where the Cambridge Greensand or nodule-bed begins, and it is believed that this nodule-bed, which forms the base of the Chalk Marl and contains phosphatic fossils derived from the zone of *Ammonites rostratus*, has resulted from the erosion and destruction of the Upper Gault marls. In other words, these marls originally extended as a continuous deposit through the area which is now occupied by the Cambridge Greensand, but were gradually removed by the action of a strong current which swept the sea floor, carrying away the finer sediment and leaving only the heavy phosphatic nodules and some of the sandy matter to form the basement-bed of the Chalk.[1]

There are several seams of phosphatic nodules in the Lower Gault, one of which has been worked at Campton, near Shefford. The higher nodule-bed, lying at the base of the Upper Gault, has also been worked nearly as far as Eggington in Bedfordshire.

The thickness of the Lower Gault varies from 150 feet at Billington and Stanbridge on the west to 180 at Arlesey and Hinxworth on the east.

A thin lenticular band of glauconitic sand caps the Gault marls near Eddlesborough and Totternhoe, but disappears before the Cambridge Greensand sets in.

Bedfordshire.

Lower Gault.

The Gault is exposed in several brickyards near Leighton Buzzard, and two sections are of special interest. They both show its base, but in one case there is a gradual passage down to the Lower Greensand, and in the other there is not, a fact which suggests that there was here a bank of Lower Greensand which caused an interruption to the even deposition of the Gault clays.

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[1] See paper "On the Relations of the Cambridge Gault and Greensand," Quart. Journ. Geol. Soc., vol. xxxi., p. 256.

The first section is in a brickyard south of the town, and the succession shown in 1884 was as follows:—

	Feet.
Dark-grey clay with phosphate nodules - - - - -	4
Dark-grey sandy clay, with some sandy phosphates and much fossil wood - - - - - - -	3
Tough clayey sand full of small pebbles - -	2
Coarse yellow sand, obliquely bedded - - -	6

Each bed seemed to pass into that below, though the pebbly bed doubtless indicates a certain amount of current erosion.

North of Leighton a strip of Gault lies on the southern slope of the Lower Greensand which forms Heath Hill, and the base of the Gault is shown in a sand-pit, where 14 feet of dark-grey clay with small patches of bright-red clay at the base rest directly on yellow sand with a well-marked plane of division. This occurrence of red clay is significant in connection with the age and origin of the red marl and red chalk of Norfolk.

Close by this pit is a brickyard which shows about 10 feet of bluish-grey clay with a seam of phosphatic nodules in the middle. This nodule bed appears to be a continuation of that described on p. 281, for it contains a similar mixture of Lower and Upper Gault species. The following is a list of the species found by myself:—

Ammonites Beudanti.
„ cristatus.
„ interruptus.
„ lautus.
„ ochetonotus.
„ rostratus.
„ splendens.
„ varicosus.
Hamites intermedius.
Belemnites minimus.
„ „ var attenuatus.
Dentalium decussatum.
Exogyra rauliniana.
Ostrea vesicularis.
Gervillia solenoides.
Inoceramus concentricus.
„ sulcatus.
„ tenuis ?
Nucula pectinata.
Plicatula pectinoides.
„ sigillina.
Terebratula biplicata.
Trochocyathus angulatus.
„ harveyanus.

For some distance east of Leighton Heath the Lower Gault is almost entirely concealed by Drift deposits, but its surface is exposed again along a tract lying south of Flitton, Silsoe, and Shefford. There are also many small outliers on the slopes of the Lower Greensands to the north of the Ivel valley. Thus near the old church at Clophill small pits (open in 1884) showed several feet of grey clay with phosphatic nodules, passing down through sandy clay into clayey sand, the last enclosing large arenaceo-phosphatic nodules like those which occur in the zone of *Ammonites mammillaris* at Folkestone and elsewhere. This bed rests on yellow and brown sand.

In 1874 a layer of phosphatic nodules was worked at Campton near Shefford, and the well at the works was stated to be 28 feet deep through clay into sand, so that the seam must lie between 20 and 25 feet from the base of the Gault. The nodules lay in a bed of light-grey clay, and were scattered through a thickness varying from 9 inches to 2 feet; with them were some grains of

glauconite, but not enough to make the clay sandy. The clay underneath the bed becomes rapidly darker. *Belemnites minimus* was so abundant that they had to be picked out by hand after the nodules were washed and before they were sent away. Other fossils were not so abundant, but the following were found [1]:—

Ammonites auritus.	Natica Genti.
„ Beudanti.	Rostellaria elongata.
„ interruptus.	Plicatula pectinoides.
„ lautus.	Inoceramus concentricus.
Belemnites minimus.	„ „ (large variety).
„ „ var attenuatus.	Nucula pectinata.
Hamites rotundus.	Terebratula biplicata.

It is noticeable that though this nodule-bed occurs at about the same horizon as that at Heath (p. 285) and those at Ford and Dinton (p. 277), yet, with the exception of *Terebratula biplicata*, the assemblage is essentially a Lower Gault one without any admixture of Upper Gault Ammonites such as occur at the other localities.

The higher part of the Lower Gault is well exposed in the brickyard and cement works at Arlesey. Here clay is sometimes dug to a depth of 50 feet; the lower part is dark, but the upper part is lighter and more marly; analyses (see p. 319) show that it contains from 26 to 31 per cent. of carbonate of lime.

Upper Gault.

The Upper Gault of Bedfordshire is a continuation of that of Bucks, and the same layer of phosphatic nodules is found at its base, at Billington, Stourbridge, and Eggington. The Upper Gault exposed in the brickyards of Eggington and Fancourt is a very marly clay, containing about 50 per cent. of carbonate of lime and drying to a very light grey so as to resemble some parts of the Chalk Marl. When examined under the microscope this resemblance is found to be a real one, for Mr. W. Hill describes it as consisting of calcareous matter in a fine state of division enclosing many small calcareous particles which are probably shell-fragments and some tests of foraminifera (*see* also Chapter xxiv.). This light-grey marl passes up into a darker grey sandy and micaceous marl.

When followed eastward the Upper Gault is found to diminish rapidly in thickness, so that the basement nodule-bed is gradually brought nearer and nearer to the Chalk. A nodule-bed surmounted by light-grey marly clay was seen in a shallow excavation by the roadside N.W. of Grange Mill near Sharpenhoe. The same bed crops out on the surface north-west of Great Faldo farm, and has been found by trial-borings about 18 feet below the surface of the ground near Brookend and not far from the outcrop of the nodule-bed at the base of the Chalk Marl, which bed was formerly worked for "coprolites" at this place. From these facts it would appear that the thickness of the Upper Gault is here reduced to between 25 and 30 feet, and there can be little

[1] See Quart. Journ. Geol. Soc., vol. xx. i. p. 279 (1875).

doubt that the Chalk Marl spreads transgressively across the Upper Gault between Barton and Higham Gobion, so as to cut through the Gault nodule-bed and rest on the Lower Gault near Shillington.

Upper Greensand.

The soft greensand, which dies out for a short distance in East Bucks, sets in again to the west of Eddlesborough, and can be traced by Eaton Bray, Totternhoe, Tilsworth, and Kateshill. It consists of fine yellowish-grey micaceous sand passing up into dark-green glauconitic-sand, which in turn passes up into the glauconitic marl that forms the base of the Chalk Marl. The extreme thickness of the Greensand is not more than 20 feet

In the road-cutting south of Kateshill there is a hard calcareous shale containing *Avicula gryphæoides* and glauconitic grains. Whether this is a bed in the Greensand or at the base of the Chalk Marl is difficult to say, for the exposure is obscure and overgrown. The land to the eastward is covered by Drift, so that the exact place where the Greensand terminates is not yet known, but is probably near Charlton, for east of this the base of the Chalk Marl descends to a lower level and takes on the character of the Cambridge Greensand or nodule-bed.

CAMBRIDGESHIRE.

The Gault of Cambridgeshire is believed to belong almost entirely to the Lower Gault. At or near its base there is generally a layer of phosphatic nodules with *Ammonites interruptus*, but there is no evidence that the zone of *Am. mammillatus* is represented.

In the highest beds at Newnham and Barnwell near Cambridge one or two specimens of *Ammonites rostratus* have been found; and this might be taken to indicate that the Upper Gault comes in there if we did not bear in mind that this and other Upper Gault Ammonites occur not infrequently in the Lower Gault of Bucks (*see* p. 278). In the absence of other evidence it is clearly unsafe to base any conclusion on the occurrence of *Ammonites rostratus* in this part of England; and in its general lithological characters the Cambridge Gault resembles that of the Lower Gault elsewhere.

The upper surface of the Gault is eroded and worn into a series of irregular hollows, ridges, and troughs. It is clear that a considerable thickness of material has been removed, and the riddlings of this in the shape of phosphatic nodules and fossils are to be found in the nodule-bed at the base of the overlying Chalk, a bed which was formerly called Upper Greensand and is still often spoken of as the Cambridge Greensand.

But although the greater part of the Gault in Cambridgeshire belongs undoubtedly to the Lower Gault, there are some facts which indicate the probability of true Upper Gault coming in again to the north-east of Cambridge.

Some suggestive evidence is to be found in the different assemblages of fossils and phosphate nodules that are found in

the Cambridge coprolite-bed at different localities along its course. Where this bed first sets in near Barton in Bedfordshire a large number of the phosphates are light-grey in colour, and the fossils, which are essentially Upper Gault forms, are chiefly among these light-coloured phosphates. In East Bedfordshire and in the extreme south-west of Cambridgeshire the phosphates are very dark-coloured, almost black, fossil mollusca are very few in number, and all are much rolled and worn.

In the neighbourhood of Cambridge the phosphates are still chiefly black, but fossils of all kinds are very abundant, and they include many species which at Folkestone and elsewhere occur chiefly in the upper part of the Lower Gault. This facies extends as far north as Horningsey; but further to the north-east, where the "coprolite bed" was worked beneath the border of the fen-country near Swaffham Prior, Reach, and Burwell, the contents of the seam had a different aspect. As stated in the memoir describing this area,[1] the phosphate nodules extracted from the pits of this district "exhibited different characters from those obtained nearer Cambridge; there was a much greater proportion of lighter-coloured phosphates, and the fossils which occurred among these had not apparently been subjected to much rolling, but retained their shells in a more perfect state than usual, *Terebratula*, *Rhynchonella*, and *Exogyra* being especially common and well preserved. . . . Amongst the darker nodules are some which have a greenish exterior, and the whole assemblage has a different aspect from those [of the pits] to the south, as if resulting from the erosion of differently constituted beds in the Gault."

At a spot in the fen about half a mile north of Reach, where coprolites were worked in 1872–3, the Cambridge Greensand was only a few feet from the surface, and was underlain by light-grey Gault; in this and about 8 feet below the Cambridge bed there had been discovered another layer of nodules, and both were worked at the same time, so that the washed heap contained nodules and fossils from both seams. Many of the nodules were light buff-coloured phosphates, which, being softer than the black stones, were worn in the washing process but did not present a worn appearance in the unwashed material. The fossils were all of essentially Upper Gault species, and the following were particularly abundant: *Terebratula biplicata*, *Rhynchonella sulcata*, and *Exogyra rauliniana*.

The occurrence of such a bed in the Gault and the similarity between the fossils in the Greensand of this locality and those in the same bed at Barton, where it certainly overlies Upper Gault, is very significant. It may be reasonably inferred that the Gault near Reach and Soham, though only 90 feet thick, includes clays which belong to the Upper Gault or zone of *Ammonites rostratus.*

With respect to the thickness of the Gault, there is a great diminution in its range through Cambridgeshire, but there is also much local variation. Many borings were made during the time that the phosphatic nodules were dug from the Cambridge Greensand, and many of these are recorded in the Memoir above

[1] "Geology of the neighbourhood of Cambridge," 1881, p. 38.

quoted. They seem to show that besides the small irregularities in the surface of the Gault there are more extensive hollows on a larger scale, the bottoms of which are often 30 feet lower than the intervening ridges; this is especially noticeable at Whaddon, Haslingfield, and Barnwell near Cambridge.

On the borders of Bedfordshire, near Ashwell and Guilden Morden, the Gault is never less than 180 feet thick, and near Reach and Soham it is never more than 100 feet, but between these places there is much variation, as shown in the following table:—

Ashwell and Guilden Morden	180 to 200 ft.
Whaddon and Bassingbourn	115 „ 170 „
Barrington and Shelford	150 „ 170 „
Haslingfield - -	130 „ 150 „
Grantchester and Cambridge	115 „ 130 „
Barnwell and Coldham Common	110 „ 140 „
Horningsea and Bottisham -	about 120 „
Reach and Soham -	90 to 100 „

The following is an account of a recent boring, made in 1897, at Shepreth, 5 miles N.E. of Royston, for Mr. Gildea, of the Rhee Valley Cement Works, by Mr. G. Ingold, of Bishop's Stortford. The account is drawn up from particulars furnished by Mr. Gildea, and from an inspection of specimens in the possession of Mr. Ingold.

	Shepreth Boring.	Thickness		Depth	
		Feet.	*Ins.*	*Feet.*	*Ins.*
	Sand, gravel, and patches of marl -	5	0	5	0
Chalk Marl.	Yellow marl - - - -	10	0	15	0
Chalk Marl.	Bluish marl - - -	36	0	51	0
Chalk Marl.	Coprolite bed (Cambridge greensand)	1	0	52	0
Gault 145½ feet.	Blue gault (samples of light grey clay from 53, 77 and 127 feet) - - - - - -	98	0	150	0
Gault 145½ feet.	Hard band with coprolites (sample of buff-coloured phosphate-nodules from 155 feet)-	5	0	155	0
Gault 145½ feet.	Blue gault (samples of light-grey clay from 160, 173, and 175, of darker grey clay streaked with light grey from 189, 193, and 200 feet) - - -	45	0	200	0
Gault 145½ feet.	Hard band with coprolites (large lumps of blackish phosphate-nodules)	1	6	201	6
Gault 145½ feet.	Very hard clay - -	6	0	207	6
Lower Greensand 33½ feet.	Hard green sandy clay (sample from 208, not a clay but a coarse pebbly sand)	3	6	211	0
Lower Greensand 33½ feet.	Rock (brown quartz-sand with a piece of a large arenaceo-phosphatic nodule)		6	211	6
Lower Greensand 33½ feet.	Compact dark greensand (sample of rather coarse yellow sand from 220 feet) -	22	6	234	0
Lower Greensand 33½ feet.	Darker loose greensand (sample of grey quartz-sand from 235 feet) . - -	2	0	236	0
Lower Greensand 33½ feet.	Dark clayey band with pyrites nodules (sample from 238 feet of dark grey sand mixed with a little clay) - - - - - -	3	0	239	0
Lower Greensand 33½ feet.	Loose sand - - - - - - -	2	0	241	0

Shepreth is a mile south of Barrington. There is no glauconite in the so-called "greensand" below the Gault.

These facts are indicated diagrammatically in Fig. 78, which also shows the probable position originally occupied by the Upper Gault and how far it has been removed by subsequent erosion.

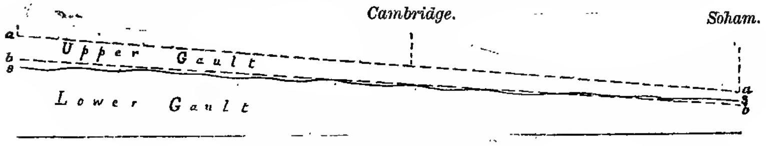
The lower portion of the Gault outcrop and its boundary line are almost entirely concealed by Glacial and Post-glacial deposits, being only traceable for a short space near Gamlingay, and again by Lolworth, Oakington, and Cottenham.

The base of the Gault was formerly exposed in a brickyard 300 yards west of Gamlingay Station, and was seen by Mr. Teall in 1873, who says "the upper part of the section there seen consisted of light-blue Gault with numerous Ammonites (*Am. interruptus*) and nodules, which gradually passed downwards into yellow sand."[1]

The base of the Gault emerges from the Fens near Upware and Spinny Abbey west of Soham, and an excavation was made a little to the north of Upware by Mr. H. Keeping in 1868,[2] the details of which are shown in Fig. 79, reproduced from a drawing subsequently made by Mr. W. Keeping and published in 1883.[3]

It is doubtful whether the clay without fossils (*c*) really belongs

FIG. 78. *Diagram to show erosion of Gault in Cambridgeshire.*



Distance about 30 miles.

a. a. Original top of Upper Gault. b. b. Top of Lower Gault.
s. s. Present surface of Gault.

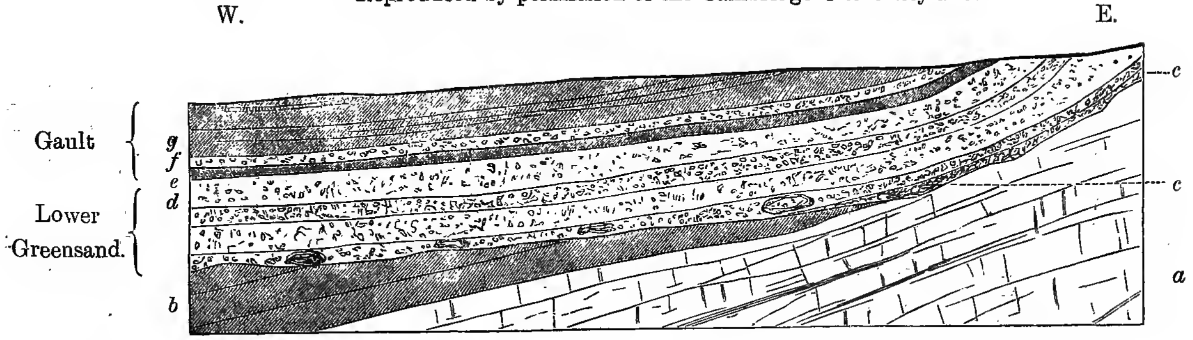
to the Gault, as Mr. Keeping supposed. In sections subsequently exposed by the "coprolite diggings," and seen by Prof. Bonney and myself, the nodule-bed at the base of the Gault rested on a clayey sand which seemed to belong rather to the sands than to the Gault.[4] In one of these sections the clay with phosphatic nodules certainly rested irregularly on the clayey sand. The fossils found here by Mr. H. Keeping and Prof. Bonney are listed below:—

Ammonites interruptus.	Nucula ovata.
Hamites sp.	„ pectinata.
Belemnites attenuatus.	Inoceramus concentricus.
„ minimus.	Pecten (Neithea) 5-costatus.
Dentalium ellipticum.	

[1] "The Potton and Wicken Phosphatic Deposits." Sedgwick Prize Essay, 1875, p. 24.
[2] Geol. Mag., vol. v. p. 272.
[3] The Fossils and Palæontological Affinities of the Neocomian Deposits of Upware and Brickhill, Cambridge," 1883, pp. 3–7.
[4] See "Cambridgeshire Geology," by Prof. Bonney, pp. 64, 65, and Mem. Geol. Survey, Expl. of Sheet 51 N.E. and N.W., p. 24.

FIG. 79.—*Section at Upware, Cambridgeshire.* Drawn by W. KEEPING from the information obtained by his father (H. KEEPING).[1]

Reproduced by permission of the Cambridge University Press.



Gault { *g.* Gault clay without fossils, about 7 feet.
f. Layer of phosphatic nodules with many fossils, about 5 inches.
e. Clay without fossils, about 1 foot. }

Lower Greensand { *d.* Yellowish sands with two layers of light-brown phosphatic nodules and pebbles of quartz, quartzite, chert, and iron-sandstone, resting unconformably on the clay below, about 12 feet.
c. Rubble of Corallian where the sands abut against that rock. }

b. Kimeridge Clay.

a. Corallian (Upware Limestone).

[1] W. Keeping, "Fossils of Upware and Brickhill," 1883, p. 4; reprinted in "Geology of parts of Cambridgeshire and Suffolk," p. 27. See also H. B. Woodward, "Jurassic Rocks of Britain," vol. v. p. 145.

No other good exposure of the zone of *Ammonites interruptus* has been seen, but during the survey of the district phosphatic nodules with fragments of that Ammonite and of *Belemnites minimus* were found on the surface of the fields north-west of Landbeach. The same fossils have been brought up from near the base of the clay in boring near Haslingfield and Cambridge.

A brickyard at Impington, open in 1876, exposed the clay occurring at a height of from 60 to 70 feet above the base of the Gault,[1] the section being as follows:—

	Feet.
Disturbed clay with pockets of gravel	4
Hard grey clay	10
Layer containing phosphatic nodules ("stony spit")	0½
Clean dark clay with fragments of Inocerami	6

A brickyard at Eversden is at a higher horizon, probably between 80 and 90 feet from the base and 40 or 50 feet from the local top of the Gault. The clay here is dark bluish-grey, and includes a thin layer, not quite continuous, of dull brick-red silty clay which is traversed by pipings (? annelid borings) filled with grey silt. Scattered phosphatic nodules occur and a few fossils, *Pentacrinus Fittoni* being the commonest.

The highest part of the Gault is well exposed in the brickyards at Barnwell near Cambridge. The clay here is sometimes dug to a depth of 50 or 60 feet, and the deeper part is said to be much darker in colour; the upper part is of a dark slate tint, drying to a lighter grey, and contains many small phosphatic nodules which are generally grey or buff outside but blackish within; these nodules occur frequently along definite planes, but some are scattered throughout. Ferruginous concretions also occur, which the workmen call "rugg-stones"; these are nodules of iron-pyrites which have become oxidised with the formation of small crystals of selenite, the interior being generally filled with a brown powder.

The only common fossil in these brickyards is *Plicatula pectinoides*, but the following species have been found[2]:—

Ichthyosaurus (vertebræ).
Rhinochelys (humerus).
Cimolichthys striatus.
Ptychodus (dorsal spine).
Ammonites rostratus.
Ammonites raulinianus.

Plicatula pectinoides.
Ostrea sp.
Terebratula biplicata.
Pseudodiadema (spines).
Trochocyathus angulatus.

At Roslyn Hole, near Ely, a large mass or boulder of Gault and Chalk Marl with the Cambridge Greensand occurred in the

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[1] This is inferred from the depth of a boring at Histon Fruit Mills, where there is 65 feet of gravel and Gault.

[2] See Bonney's "Cambridgeshire Geology," p. 29 (1875).

boulder-clay, and the following fossils have been recorded from the Gault portion of it:—

Ammonites rostratus.	Inoceramus sulcatus.
„ varicosus.	„ concentricus.
Belemnites minimus.	Perna sp.
„ var. attenuatus	Nucula pectinata.
Cerithium ornatissinum.	Pentacrinus Fittoni.
Dentalium ellipticum.	

In one of the southern counties this assemblage would be regarded as indicating the existence of Upper Gault, and it is quite possible (as already stated) that the clay immediately underlying the Cambridge Greensand between Ely and Soham does belong to the zone of *Ammonites rostratus*.

CHAPTER XXI.

GAULT AND RED CHALK (SELBORNIAN), IN NORFOLK.

General Description.

Beyond Soham the Gault passes beneath the Fenland deposits of Suffolk and West Norfolk and is concealed for a distance of about 14 miles. It emerges again near Stoke Ferry, where its thickness has been proved by a boring made near the railway-station in 1883, and traversing the following beds :—

		Feet.
Drift	Sand and water	25
Lower Chalk	Chalk -	13½
	Yellow marl	3
Gault -	Blue clay -	56
	Dark green sand	2
Lower Greensand -	Beds of rock and sand	15
		114½

There is no doubt, as will appear from the sequel, that both Upper and Lower Gault are represented in this thickness of 58 feet, and it is probable that more than half of it belongs to the Upper division or zone of *Ammonites rostratus* (see Fig. 76). There is moreover a possibility that the basal zone of *Ammonites mammillatus* is represented in the green sand at the base.

The whole of the Gault clay near Stoke and Dereham is very marly, and the upper part becomes more calcareous northward; this marl at Grimston and Roydon containing as much as 66 per cent. of carbonate of lime, and having in it a layer of red marl which contains from 64 to 69 per cent., and a layer of limestone which contains about 89½ per cent. of the same carbonate.

When the Gault is followed northward the marls are found to thin out, and at Hunstanton there is only about 3½ feet of red earthy limestone between the lower Cretaceous sands and the Lower Chalk. This limestone is known as "*the Red Chalk,*" and it naturally became a question whether it represents the Gault in a very condensed form, or whether the Gault had entirely thinned out and disappeared, the red rock being in that case the local base of the Lower Chalk.

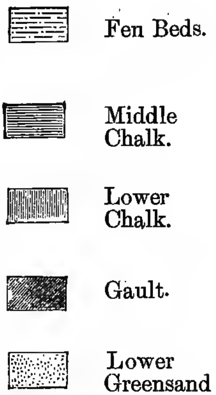
The history of opinion on this question is a long one. The first to express an opinion was Professor Sedgwick in 1826, who believed it to represent "the Cambridge Galt[1];" the same view was held by C. B. Rose in 1835,[2] by Fitton in 1836,[3] by Davidson in 1852,[4] and apparently

[1] Annals of Philosophy, Ser. 2, vol. xi. p. 342.
[2] Phil Mag. Ser. 3, vol. vii. pp. 172, 188, 275.
[3] Trans. Geol. Soc., Ser. 2, vol. iv. p. 312.
[4] Brit. Cret. Brach. Palæont. Soc. p 2.

Fig. 80.—*Map of outcrop of Cretaceous Rocks in West Suffolk and Norfolk.*[1]

(Reduced from the maps of the Geological Survey.)

Scale, one inch = eight miles.



[1] Quart. Journ. Geol. Soc., vol. xliii., p. 546.

by E. Forbes in 1859,[1] and by the Rev. T. Wiltshire in 1869.[2] First to dissent was Mr. H. G. Seeley in 1861,[3] who considered it to be the equivalent of the Upper Greensand, chiefly because most of the Red Chalk fossils occur in the Cambridge Greensand which was at that time supposed to be Upper Greensand.

In 1876, Dr. C. Barrois described the Hunstanton section, referring the Red Chalk to his zone of *Ammonites inflatus* (*i.e.* Upper Gault), considering the zone of *Pecten asper* to be absent so that the former zone is succeeded directly by the basement-bed of the Chalk Marl. This was a very near approximation to the truth.

In 1878 the late Mr. John Gunn published a brief note on the red chalk[4] in which he maintained that the fossils "of the latest type must be used in identifying the period" of the bed, suggested that the Gault and Greensand species were derived fossils, and concluded that the rock itself formed the basement-bed of the "true chalk series." This view was adopted and amplified by Mr. Whitaker in his address to the Norwich Geological Society in 1883.[5] Mr. Whitaker discusses both the palæontological and the stratigrapical facts, laying stress on the number of fossils which do not elsewhere occur below the Chalk Marl.

In 1886, an endeavour was made by Mr. William Hill and myself to obtain more definite and detailed stratigraphical evidence concerning the relations of the Chalk Marl, Gault, and Red Chalk in West Norfolk, and the results were published in 1887.[6] In this paper it was claimed that the following points had been ascertained :—

1. That the *soft* Chalk Marl thins out entirely within the area of Sheet 65 (before reaching Roydon).

2. That the base of the Chalk Marl at Grimston, Roydon, is a hard cream-coloured limestone, which passes northward into the so-called "sponge bed of Hunstanton."

3. That the soft grey marl, which lies below this hard bed at Roydon, and which was taken to be part of the Chalk Marl by Mr. Whitaker is really Gault, and that it contains a band of red marl.

4. That this grey marl extends as far north as Dersingham where it passes down into a brown and red marly clay (about four feet thick).

We infer that this grey and red marl is replaced between Dersingham and Heacham by the Red Chalk, and consequently that the latter is the actual stratigraphical equivalent of the Gault. With regard to the fossils, they cannot accept the doctrine that those of the latest type or highest range should be relied on as guides to the age of the bed. We regard the so-called Chalk species found in the Red Chalk as indicators of a greater depth of water than that of the southern Gault, and point to the occurrence of two of them, viz., *Ostrea curvirostris*, and *Terebratulina gracilis* [= *triangularis*], in the Norfolk Gault.

It may be observed that Prof. Seeley's palæontological argument lost all its force when the phosphatic fossils of the Cambridge Greensand were proved to have been derived from the Gault, and when that bed was shown to be the base of the Chalk and not a representative of the Upper Greensand. The existence of many of the same species in the Red Chalk and among the

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[1] Catalogue of Rock specimens in Jermyn Street Museum, Ed. 2, p. 86.
[2] Quart. Journ. Geol. Soc., vol. 25, p. 185.
[3] Ann Nat. Hist., Ser. 3, vol. vii. p. 233.
[4] Proc. Norwich Geol. Soc., part 1, p. 23.
[5] Proc. Norwich Geol. Soc., part vii., p. 212.
[6] Jukes-Browne and W. Hill: "On the lower part of the Upper Cretaceous Series in West Suffolk and Norfolk." Quart. Journ. Geol. Soc., vol. xliii. pp. 544, 598.

Cambridge phosphates is of course an argument for the Red Chalk being of Gault age.

It is true that there is an Upper Greensand element in the Red Chalk, because part of that Greensand is equivalent to the upper part of the Gault; and in this way it may be said that the Red rock represents both Gault and Upper Greensand, but not the whole of the latter.

Dr. Barrois was right in stating that the zone of *Pecten asper* is wanting in Norfolk, and it is a fact that in the north-west of this county the normal succession is a passage from Upper Gault to Chalk Marl without any development of *Pecten asper* beds or of the subzone of *Stauronema Carteri.*

It is also incontrovertible that the Cephalopoda of the Red Chalk are essentially Gault species, that they include characteristic species both of the Lower and the Upper Gault, and that there is no ground for supposing any of them to be derived.

When to this statement it is added that none of the Cephalopods which are characteristic of the Chalk Marl, such as *Ammonites varians, Am. Mantelli, Scaphites æqualis,* or *Turrilites tuberculatus,* have ever been found in the Red Chalk, it will be seen that the reasons for regarding this red limestone as a condensed equivalent of the Norfolk Gault, and of that alone, are very strong.

STRATIGRAPHICAL DETAILS.

Gault.

The basement-beds of the Gault were formerly worked at West Dereham between Stoke Ferry and Downham Market. The workings were seen by me in June, 1874, and a little later by Mr. Teall, who published an account of them in 1875,[1] the spot where they were first worked being about half a mile west of the church. Here the beds exposed were as follows:—

5. Surface soil with flints lying irregularly on the clay.
4. Light bluish clay with *Ammonites interruptus*, passing down into grey clay mottled with whitish streaks, and containing many phosphatic nodules, 5 or 6 feet.
3. Light-brown sand with phosphatic concretions and numerous fossils, about 1 foot.
2. Hard sandstone also containing phosphatic concretions, 5 or 6 inches.
1. Reddish sand below, but not exposed.

The beds dug for the phosphatic nodules were 3 and the lower part of 4, and the fossils were of course mixed in the washed heap, but Mr. Teall refers 3 to the zone of *Ammonites mammillatus* and there can be no doubt that 4 belongs to the zone of *Am. interruptus.*

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1 "The Potton and Wicken Phosphatic Deposits" (Sedgwick Prize Essay), pp 20 to 22.

Mr. Teall observes, "There is no break between (3) and (4), the sand gradually becoming finer and more argillaceous until it is replaced entirely by the grey clay, and . . . . the nodules are not derived but are simply portions of the matrix highly charged with phosphatic matter. Thus where the matrix is a coarse sand the nodules are of coarse sand, and where the matrix is a fine clay the nodules are of the same material."

Mr. W. Keeping visited the locality in 1876 and found a deeper excavation in consequence of the nodule-beds having been followed further to the eastward so that 10 feet of clay was exposed. He describes the nodules in the clay as of the usual Gault type, while those in the underlying sand "are rather large rounded nodules, but unworn and of two kinds, (1) those of a dirty white colour, and (2) the dark-green ones. . . . Breaking a nodule to expose a freshly-fractured surface, we see it is a quartzose . . . sandstone of varying coarseness, the grains cemented together by a dense matrix of phosphate of lime and iron-oxide. The dark-green nodules are of an older date of origin, for they are frequently included within the paler ones. . . . The fossils are principally in the state of internal casts in a dark variety of phosphate."[1]

Mr. Keeping also separated the fossils of the Gault clay from those of the sand, and gave the following lists:—

1. From the clay.	2. From the sand.
Ammonites interruptus.	Ammonites Beudanti.
" splendens.	Pleurotomaria.
Hamites (2 species).	Solarium.
Belemnites attenuatus.	Aporrhais.
Inoceramus concentricus.	Cyprina ligeriensis.
" sulcatus.	" sp.
Nucula pectinata.	Pecten orbicularis.
	" (Neithea) Morrisi.
	Spondylus sp.

In 1886 I visited West Dereham again and found other excavations which showed quite a different succession from that at the spot where the first pits were opened in 1874 and 1876. The new pits were in a field about a mile W.N.W. of the church, and the section at the N.E. end of the trench was as follows:—

		Ft.	in.
Gault	Bluish-grey clay, marly and drying light-grey -	11	0
	Dark sandy clay with phosphatic nodules -	0	9
Lower Greensand.	Brownish sand, seen for - -	2 to 3	0

Here there was only one nodule-bed instead of two, and this was distinctly at the base of the Gault, for it rested unevenly on the underlying brown sand, and consisted of clay mixed with grains of quartz and glauconite and passing up into the clean clay above. The phosphatic nodules were very dark, nearly black, and of the sandy variety, some enclosing large grains of sand. Fossils were not abundant, except fragments of *Ammo-*

[1] "The Fossils of Upware, &c." (Sedgwick Prize Essay, 1883) pp. 11-12.

nites Beudanti, and pieces of wood often bored by *Pholas*. Another pit near the main road five-eighths of a mile south-west of the church showed a similar section.

The following species were found on the washed heaps:—

Ammonites Beudanti,	Terebratula prælonga.

These pits were visited by Mr. C. Reid in the same year, who specially collected fossils from the marly clay; these were identified by Mr. G. Sharman, and they give the following list[1]:—

Pycnodus sp.	Ostrea acutirostris.
Odontaspis gracilis.	„ vesicularis.
Cimolichthys striatus.	Inoceramus concentricus.
Beryx sp.	Lima.
Ammonites interruptus.	Nucula pectinata.
Hamites sp.	Pecten orbicularis.
Belemnites attenuatus.	„ quinquecostatus.
„ minimus.	Plicatula pectinoides.
„ ultimus.	Pholadidea (in wood).
Dentalium ellipticum.	Rhynchonella.
Anomia.	Terebratula biplicata.
Exogyra haliotoidea.	Pseudodiadema (spine).
	Pentacrinus Fittoni.

Near "Muzzle Farm," about a mile west of West Dereham there is a small outlier of Gault in which is an old clay-pit, and from this the following fossils have been obtained by Mr. Reid and Mr. W. Hill. The Ammonites only occurred below the present floor of the pit, and were obtained by digging.

Ammonites interruptus.	Plicatula pectinoides.
Belemnites attenuatus.	Kingena lima.
„ minimus.	Terebratula biplicata.
Nautilus sp.	Terebratulina gracilis.
Inoceramus concentricus.	[? = triangularis.]
Ostrea vesicularis.	Pentacrinus Fittoni.
Nucula pectinata.	Pseudodiadema (spines).

The higher beds near Wereham consist of a marly clay which has a bright bluish-grey tint when damp, but dries to a light grey and then much resembles Chalk Marl. So light-coloured and marly indeed is the whole of the Gault in this district that it was suggested by Messrs. Reid and Sharman in 1886 that it was not Gault but Chalk Marl.[2] Careful examination of the district and search for fossils showed that this view could not be maintained, but that the Chalk Marl was fully developed above the Gault and had at its base a layer of sandy glauconitic marl resting directly on the blue marly clay.[3]

The succession is strikingly similar to that near Totternhoe and Fancourt in Bedfordshire, just before the setting in of the

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[1] See Geol. Mag. Dec. 3, vol. iii. p. 57. See also "Geology of South-western Norfolk," Mem. Geol. Survey, p. 26 (1893).

[2] See Geol. Mag. Dec. III., vol. iii., p. 55.

[3] See Geol. Mag. Dec. III., vol. iv., p. 74, and Quart. Journ. Geol. Soc., vol. xliii., p. 549, *et seq.*

Cambridge Greensand, where the calcareous Upper Gault is directly succeeded by a sandy glauconitic bed without phosphates at the base of the Chalk Marl. From these facts and from other evidence a little further north we may safely infer that the upper portion of the Norfolk Gault is equivalent to the Upper Gault of Bedford and Bucks and that it had not suffered erosion before the deposition of the Chalk Marl.

No good exposures of the Upper Gault (zone of *Ammonites rostratus*) have been seen near Dereham, but 14 miles further north part of it is exposed in a shallow railway-cutting near Roydon, north-east of Grimston Road Station, and consists of the following beds :—

		Ft.	*in.*
Soil and grey marl -	-	?	
Pale yellowish-grey limestone,	- about	0	8
Grey marly clay,	,,	0	4
Reddish-pink marl,	,,	1	2
Grey marl, -	,,	2	0
Hard bluish-grey limestone,	,,	0	10
Dark-grey marly clay,	,,	5	0
		10	0

The same succession can be made out in the watercourse of the brook west of Grimston church, and in that below Sow's Head spring, with the addition of some thickness (perhaps 12 feet) of grey marly clay, with occasional *Belemnites*, above the upper limestone bed. In the lower limestone at these three localities the following fossils were found by Mr. W. Hill and identified by me :—

Belemnites minimus.
Ammonites lautus.
,, rostratus.
,, varicosus.
Inoceramus concentricus.
,, sulcatus.
Terebratula biplicata.
Pentacrinus Fittoni.

A little further north, in a small quarry about half a mile N.N.E. of Roydon church, a boring was made in 1886 for and under the superintendence of Mr. Hill. This passed completely through the Gault, and proved it to be less than 20 feet thick. The section obtained by clearing and digging below the pit face and by boring was as follows :—

		Feet.	*in.*
Chalk	Hard greyish gritty chalk, with green-coated nodules at its base (the *Inoceramus* bed) -	6	0
	Very hard cream-white chalk, becoming yellower downward and passing into the bed below as layers or lumps separated by marl .	5	6
Gault	Tough grey marly clay with *Belemnites* - -	10	0
	Yellowish marly clay, stained and blotched with red, one drawing of the auger (5 inches) being mostly red - - -	1	9
	Bluish-grey clay, becoming darker below, sandy and almost black at the base -	7	0
Lower Greensand (Carstone).	Brown sandstone proved to	3	0
		33	3

No hard beds were noted in boring, but subsequent examination of the cores showed that one layer of hard calcareous material had been passed through.

Another boring was made at the same time in the chalk-pit at Dersingham, about four miles further north, and a hard whitish limestone, similar to that at Roydon, was found at the base of the Chalk, below which the boring proved the following beds:—

	Feet.
Rather soft greyish-white marl, drying white -	2
Pale-yellow marl, hard and compact at first, becoming softer and browner and passing into next	2½–3
Red clayey marl, rather hard, streaked with tawny-brown and sandy near the base	2–2½
Carstone, proved for -	1½

It will be noticed that the total thickness of the Gault here is only seven feet; that the uppermost light-grey marl has thinned from 10 feet (at Roydon) to 2 feet, and has become still more calcareous, and that the blue clay of Roydon has apparently passed into red clayey marl.

Probably this condition of brown and red marl extends as far as Ingoldisthorpe, for Dr. Fitton says that at that place "I myself have seen that the red stratum is immediately succeeded by sand, the blue beds being wanting," and yet in his list of fossils from the Gault he mentions *Ammonites dentatus* (*i.e. interruptus*) "in grey sandy clay, Ingoldsthorpe," and "*Belemnites minimus*, Ingoldisthorpe, in very light grey marl, with an *Inoceramus*." [1]

The record of a boring at Holkham Hall, between 12 and 13 miles east of Hunstanton, is invested with a fresh interest by these later researches into the composition of the Gault in West Norfolk. This boring was completed in 1867, but no detailed account of it was published till 1878, when Mr. Whitaker obtained the following particulars from Mr. Shellabear, agent to Lord Leicester [2]:—

		Feet.
Drift -	Gravel - -	20
Chalk	Chalk with flints -	519
	Chalk without flints	116
Gault	Red Marl -	8
	Blue Gault - - -	10
Lower Greensand	Very hard bed of sandstone [? base of Gault] -	0½
	Sandstone, Sand. and Carstone	69½
?	Stiff clay touched at the bottom.	
		743

Mr. Whitaker remarked:—"The chief interest of the underground section thus gained is perhaps the occurrence of the bed described as 'Red Marl,' which seems to be the well-known 'Red Chalk,' at the base of the Chalk, and *overlying* a bed described as Gault." I cannot but think that if the bed here met with had been as hard as the Red Chalk of Hunstanton the

[1] See Trans. Geol. Soc., Ser. 2, vol. iv. pp. 312, 316, 317.
[2] See Proc. Norwich Geol. Soc., Part 1, p 16 (1878).

well-borer would not have called it "red marl"; and as we now know that red marl and blue gault are associated with one another between Grimston and Dersingham, it is more probable that the beds under Holkham are a continuation of the marly facies of the formation and not of the *chalky* Hunstanton facies.

Red Chalk.

From Ingoldisthorpe northward to Hunstanton the place of the Gault is taken by the Red Chalk, an earthy ferruginous limestone containing about 80 per cent. of carbonate of lime. As this has not been utilised for any commercial purpose the inland exposures are few and small. It was formerly visible in the cartway leading into the chalk-pit south-east of Heacham, but is not seen in the pit itself. It is also exposed at Snettisham and in a chalk-pit near Hunstanton Station, but the only good section of it is that in the cliffs to the northward, and it is to this that the following account relates. Near the pier the Red Rock is at the summit of the cliff, but it gradually descends as

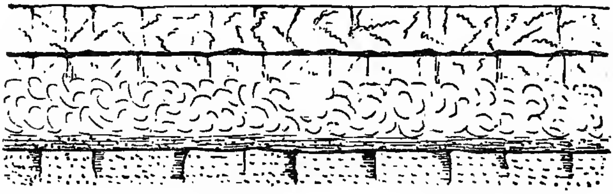

Fig. 81. *Diagram to show the structure and relations of the Red Chalk at Hunstanton.*

the cliff trends eastward, till it comes down to the beach near Old Hunstanton.

The Red Rock at Hunstanton is about four feet thick, possibly rather less in places, but it forms a very even and regular, as well as conspicuous, band along the cliff face. It rests evenly upon the surface of the Carstone, without any signs of erosion beyond the presence in its lower portion of numerous quartz grains, large and small, like those which compose the underlying sandstone.

It forms a single massive bed, not laminated nor divisible into separate layers, but at the same time it is by no means of homogeneous composition throughout. Its basal portion is softer and less calcareous than the rest, being also much more sandy, and of a deep brick-red colour. The central part of the rock (from 20 to 24 inches) is a dark red, rough and nodular limestone with few large quartz-grains, but containing many fossils. (See Fig. 81). The highest part, about a foot thick, is a hard light red or pink limestone mottled with white, and is probably more calcareous than the rest.

The upper surface of the red limestone is a marked plane of division, and the rock is separated from the overlying Chalk by an irregular seam of dark red ferruginous earth which swells out

here and there, and appears to fill spaces caused by inequalities in the under surface of the Chalk.

Some observers have thought that the different portions of the Red Rock contained a different set of fossils, but, so far as our experience goes, the difference is chiefly a matter of relative abundance, *Belemnites minimus* and *Terebratula biplicata* being most abundant in the lower part, while the highest part yields many specimens of *Inocerami* and of *Exogyra haliotoidea.* I am not aware, however, that any Ammonites have been found in the highest part.

The higher part of the Red Chalk also exhibits some of the cylindrical and branching bodies which have been regarded as parts of a Sponge, and named *Spongia paradoxica.* Portions, however, that have been sliced and examined under a microscope show no sponge-structure nor any other kind of organic structure. Prof. T. McK. Hughes has discussed these curious bodies, and concludes that they are probably "merely concretions owing their symmetry of form and regularity of arrangement to rock structure, which is more obvious in the cliff than in hand specimens."[1] They are still more abundant in the overlying bed, to which the name "Sponge Bed" has in consequence been given by some writers.

The seam of dark red earth is in places worked out by the waves, and hollow spaces are left in consequence. In some of these hollows brown sand has been found, and it has been supposed by some observers that this sand was deposited there with the red earth, but we think the sand has been washed up and driven in by the sea-waves.

A list of the fossils which have been found in the Red Chalk of Hunstanton has been given separately in the "Geology of the Borders of the Wash" (Mem. Geol. Survey), and will also be found in the Appendix at the end of this volume.

Many analyses of the Red Chalk of this locality have been made at different times, and these have been collected and published in the memoir above referred to. From these we learn that the rock contains a variable amount of peroxide of iron; the hard red nodular portions contain as much as from 37 to 42 per cent. of ferric oxide, with only 40 to 50 per cent. of carbonate of lime. Ordinary samples of the central part yield about 80 per cent. of carbonate of lime, 8 to 10 per cent. of ferric oxide, and 9 to 10 per cent. of siliceous matter. The higher and lighter coloured portion has from 82 to 84 of carbonate of lime, 6 or 7 of iron oxide, and 7 or 8 of siliceous matter. (See p. 322.)

These analyses prove the colouring matter of the rock to be peroxide of iron, but whether this was deposited with the chalky material, or has resulted from the alteration of some original ingredient, or has been subsequently introduced is much less easy to determine. The analyses also show that the ferruginous material is something more than a stain, for very little of such peroxide is sufficient to colour a rock red, 2 per cent. being

[1] Quart. Journ. Geol. Soc., vol. xl., p. 276.

enough; the quantity present in Red Chalk shows it to be a constituent of the rock, either original or altered or introduced.

If the Red Chalk occurred only where it was underlain by Carstone or ferruginous sand of any kind, it might be thought that the peroxide had been derived from that rock, for the red layers at the base of the Gault in Sussex (p. 115) and near Leighton Buzzard (p. 285) seem to have been coloured in this way. But in the case of the Red Chalk the iron can hardly have been so derived, because the bed is still red in those parts of Yorkshire where it rests on the Speeton and the Jurassic clays.[1]

It has been suggested that the red oxide has come from the thin layer of that material which overlies the Red Chalk at Hunstanton, and this view finds some support in the fact that layers of dark red marl frequently occur between the layers of red rock in Lincolnshire. It is quite possible that some colour has spread from these layers, but as pointed out by Prof. H. G. Seeley the darkest part of the Hunstanton bed is the lowest, and not that in contact with the supposed source of the colour.

Prof. Seeley has suggested[2] that the coloration is due to the decomposition of glauconite, and it must be admitted that this is a possible source of the peroxide. Mr. Hill finds that grains which seem to have been glauconite are frequent in the rock, and that in most cases they are altered into a dark brown substance which is probably peroxide of iron. But if these grains were glauconite, how did they come to be so completely decomposed and oxidised, when glauconite in other Cretaceous rocks is seldom decomposed except where exposed to the action of organic acids near the surface of the ground? This point was not discussed by Prof. Seeley.

If, however, the glauconite was gradually oxidised during the accumulation of the material which is now Red Chalk, the facts become more comprehensible. The possibility of this will be admitted when one remembers that the length of time required for the formation of this four feet of red rock was the same as that required for the deposition of 200 to 300 feet of Gault and Malmstone in the Midland counties. The accumulation of the material of the Red Chalk must have been so very slow that there would have been ample time for the decomposition of the small included grains of glauconite before they were protected by a sufficient covering of deposit.

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[1] See, however, notes on relations of Jurassic iron-ores to clays, H. B. Woodward, Jurassic Rocks of Britain, vol. v., p. 326.

[2] Ann. Mag. Nat. Hist., Ser. 3, vol. vii., p. 233, 1861.

CHAPTER XXII.

RED CHALK (SELBORNIAN) IN LINCOLNSHIRE AND YORKSHIRE.

1. Red Chalk in Lincolnshire.

Crossing the Wash and a portion of the Lincolnshire Marshland we find the outcrop of the Red Chalk again near Gunby. This distance from Hunstanton to Gunby is about 30 miles, and in this distance the thickness of the red limestone has increased to about 12 feet.

Below it are coarse yellow and brown sands, known by the name of Carstone and doubtless the equivalent of the Carstone of Norfolk, *i.e.,* the upper part of the Norfolk Lower Greensand. At the Southern end of the Lincolnshire Wolds this Carstone is 40 feet thick, but it disappears entirely in the Northern part of the county, either by thinning out or by an overlap of the Red Chalk.

Up to 1886 the Carstone was regarded as belonging to the Lower Cretaceous Series, but in that year Mr. Strahan[1] gave some reasons for considering it as the base of the Upper Cretaceous Series, believing it to be more closely connected with the Red Chalk than with the beds below. This view was adopted by Mr. Lamplugh in 1896,[2] who places the upper portion of it in his zone of *Belemnites minimus* with the Red Chalk. With these views, however, I cannot concur.

Both writers lay stress on the apparent passage between the Carstone and Red Chalk, but though there appears to be a passage I believe the latter creeps across the former, for there is a much greater thickness of Carstone in the Thoresway valley than there is at Acre House on the escarpment, and I regard its disappearance northward as a matter of overlap.[3]

At the top of the Carstone there is in some places a sort of passage-bed in the shape of a sandy clay of varying colour which contains *Belemnites minimus* and *Terebratula biplicata,* and this I regard as the base of the Upper Cretaceous Series.

There is of course no reason why a zone of *Ammonites mammillatus* should not exist in Lincolnshire, and it is a fact that the sand immediately below the gritty clay above-mentioned con-

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[1] Quart. Journ. Geol. Soc., vol. xlii., p. 486.

[2] Quart. Journ. Geol. Soc., vol. lii., p. 211.

[3] See Note on p. 110 of the Explanation of Sheet 86 Mem. Geol. Survey (1890); also Geology of Country around Lincoln (Geol. Survey), Chapter X, by A. Strahan.

tains arenaceo-phosphatic nodules like those found in that zone at Folkestone. But if that Ammonite were found at the top of the Carstone it would not oblige us to transfer the whole of the Carstone to the Gault, any more than its existence at Folkestone involves the removal of the Folkestone beds as a whole from the Lower Cretaceous Series.

At present, however, there is no proof that any portion of the Carstone should be dissociated from the rest, and the verdict on the view held by Mr. Strahan and Mr. Lamplugh must be one of "not proven," just as in the case of the "Carstone" of the Isle of Wight. (See p. 127).

Upwards the Red Chalk passes into a pink or yellowish pink limestone, which resembles, and occupies the place of, the "Sponge-bed" of Hunstanton. In many places, but not in all, the pink beds are separated from the red by a thin layer of red shaly marl.

The main outcrop of the Red Chalk forms a very irregular line along the border of the Chalk Wolds, but its general trend is from south-east to north-west. Owing also to the depth of the valleys by which the Wolds are dissected the Red Chalk and the underlying beds are exposed in a number of inliers at varying distances from the main line of escarpment. The chief of these are (1) between Claxby and Ulceby, (2) near Swaby, (3) at Ketsby, (4) a large irregular tract by Worlaby, Ruckland, Farforth and Oxcomb, (5) a small one at Withcall, (6) at Stainton and Thorpe-le-mire, (7) the Thoresway valley, (8) the Rothwell valley.

STRATIGRAPHICAL DETAILS.

The upper part of the Red Chalk is exposed in several of the quarries between Gunby and Candlesby, and good sections of the lower beds are visible near Dalby and Langton.

A road-cutting freshly made in 1881 above Dalby Hall (*see* Fig. 82) showed the following beds:—

	Feet.
Hard nodular red limestone in beds divided by layers of red clayey-marl - - - -	8
Stiff greenish sand with many phosphatic nodules	1
Coarse yellowish brown sand - up to	15

The beds are broken by several faults, and the thicknesses mentioned are the maxima exposed at different spots.

At Langton, north of the Hall, is a large quarry in the Carstone which also shows its junction with the Red Chalk thus:—

		Feet.
Red Chalk.	Red nodular chalk, with deep-red partings of marly clay, and containing black grains, up to - - -	6
	Red clay with yellow streaks, *Belemnites minimus* and *Terebratula biplicata*, and some phosphatic nodules	1
	Tough sandy clay, yellow, red, and green, with cylindrical concretions - - - -	$2\frac{1}{2}$
Carstone.	Loose sand with a few small pebbles and a layer of whitish sandy phosphatic concretions - -	2
	Coarse brown sand with rolled brown phosphatic nodules scattered throughout - . -	8
	Brown sandstone with darker ironstone veins -	18

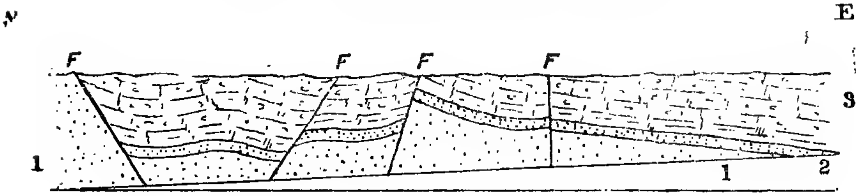
A complete section through the Red Chalk is to be found in a small quarry by the roadside north of Sutterby, where, below the yellowish-pink bed, which may be taken as the base of the Lower Chalk, there is about 12 feet referable to the Selbornian divisible as follows:—

	Feet.
3. Light-red chalk, in nodular lumps embedded in red argillaceous marl - - - - - -	5
2. Dark-red chalk in beds divided by thin layers of red shaly clay, the lower beds more argillaceous and passing into next. - - -	5
1. Red sandy clay containing small grains of quartz and lydian stone. - -	2

Belemnites minimus is common in No. 2 and abundant in 1. *Avicula gryphæoides* is common in 3. *Terebratula biplicata* occurs throughout. *Ter. capillata* was found both in 1 and 2. *Ter. semiglobosa, Inoceramus tenuis, Plicatula minima,* and *Ostrea vesicularis* occurred in 2 and 3.

There are many other exposures in the country west of Alford and Louth, but it is unnecessary to mention more than two as of special interest. The first of these is in a small inlier at Withcall, three miles S.E. of Louth, and this only shows two feet of rubbly

FIG. 82. *Road-cutting at Dalby, Lincolnshire.*



3. Red Chalk (Selbornian). 2. Greenish Sand. 1. Carstone.
F. Faults.

red chalk resting upon Carstone, but is important as the place where Mr. Hill found a specimen of *Ammonites interruptus,* the only Ammonite hitherto obtained in the Red Chalk of Lincolnshire.

A little further to the S.E., at the western end of the Withcall Tunnel, Mr. Strahan noted is a fine section through the Red Chalk and the Carstone, as given below:—

		Ft.	*in.*
Lower Chalk	- - - -	20	0
Red Chalk, about 11 feet	Pink and yellow chalk, and pale-red chalk below - - -	5	0
	Red shaly parting - - - -	0	4
	Dark-red chalk - - -	2	10
	Red shaly parting - - -	0	6
	Dark red nodular chalk, with quartz grains and flakes of ferric oxide. *Terebratula biplicata* and *Bel. minimus* are abundant.	1	6
	Red marl with grains of quartz and ferric oxide, *Belemnites* numerous - -	1	0
Greenish - yellow sandy clay with arenaceo-phosphatic concretions	- - - -	0	9-10
Carstone—yellow and brown sand, about	- - -	35	0
	about	67	0

Whether the yellowish sandy clay should be included in the Red Chalk is a doubtful point.

From this locality northward the thickness of the red beds begins to diminish. A section in the Stainton inlier showed a total thickness of 8½ feet; near Otby its thickness is only about six feet. At Thoresway above the spring near the church is the following section:—

		Feet.
White chalk with a pink bed at base		3
Red chalk	Nodular red chalk in several beds	5
	Dark-red marl with Belemnites	1
Yellow marly sand with phosphatic lumps		1
Carstone, coarse yellow and brown sands		20

In Nettleton Dale there is about four feet of Red Chalk which seems to rest directly on sandstone with little if any red or yellow marl between.

At and North of Caistor the thickness remains about the same, varying between four and five feet. At Audleby the Carstone is overlapped, and the Red Chalk rests on the Tealby Beds. A little further north it rests on Kimeridge Clay, but at Melton the Spilsby Sandstone intervenes, and at Elsham this sandstone is separated from the Red rock by two or three feet of Tealby clay, the junction here being clearly an uncomformable one. Beyond this the substratum is everywhere Kimeridge Clay.

There is therefore no question about the unconformity of the Red Chalk to the lower portion of the Lower Cretaceous Series, and as there is no proof of a break between the Tealby Beds and the Carstone, the facts are most naturally explained by a break above the Carstone with overlap of the Red Chalk.

In the north of Lincolnshire there are no good exposures of the Red Chalk, and its outcrop on the Humber is concealed by Drift.

The following fossils have been found in the Red Chalk of Lincolnshire, but more prolonged collecting would probably add to the list:—

Ammonites interruptus.	Inoceramus tenuis.
Belemnites minimus.	„ sp.
„ „ var. attenuatus.	Kingena lima.
Avicula gryphæoides.	Rhynchonella lineolata.
Ostrea vesicularis.	Terebratula biplicata.
Plicatula minima.	„ capillata.
Spondylus truncatus ?.	„ semiglobosa.
Pecten (Neithea) quinquecostatus.	Serpula sp.

2. Red Chalk in Yorkshire.

The representative of the Selbornian in Yorkshire exhibits greater lithological variation than its equivalent in Lincolnshire. Starting with a thickness and general characters similar to those of the beds in North Lincolnshire it thins gradually to the north-west till it is reduced to a bed of gritty reddish-yellow limestone only two feet thick with a sandy and pebbly basement-bed varying in thickness from 6 to 18 inches.

Again passing eastward along the northern border of the Wolds the formation changes, the limestone becomes thicker, less gritty, and more argillaceous, passing gradually into a stiff red marl, with nodular lumps of more chalky material, which has at Speeton a thickness of 30 feet. Moreover there are at its base several feet of red and brown clays which seem to form a passage between it and the Speeton Clay series below. These brown clays remind us of the similar material proved by the boring at Dersingham in Norfolk, and the overlying red marl will compare with the red bed in the Upper Gault of Roydon and Grimston, but is much less calcareous; even the higher part only contains 68 per cent. of carbonates, and of this amount 8·46 per cent. are carbonate of magnesia (*see* p. 326).

Statigraphical Details.

The following account of the principal exposures of the Red Chalk in Yorkshire is chiefly taken from Mr. W. Hill's paper,[1] with some notes from those by Prof. J. F. Blake,[2] Mr. G. W. Lamplugh,[3] and other observers.

On the north side of the Humber the Red Chalk is first seen at Welton Springs, but the first good section is in the railway-cutting about a mile east of South Cave, between the two short tunnels. Mr. Hill says, "Here it is seen to be about 7 feet thick and is of a grey colour in the centre. *Belemnites minimus* occurs commonly. It may be said to rest on Kimeridge Clay, but between it and this formation can be seen at intervals a thin layer of yellowish very fine sandy material containing roundish concretionary nodules of ironstone which show when broken a slightly oolitic structure." This appears to pass up into red clay. The section is now somewhat obscured by weathering and by the facing of the embankment, but Messrs. Middlemiss and Keeping, who saw it when fresher, give the following succession[4]:—

	Feet.	*in.*
Nodular red chalk	1	6
Pale [? pink] nodular chalk	1	3
Clayey red chalk	0	6
Grey nodular chalk	1	0
Red chalk	0	3
Yellowish-green clay	0	9
Unctuous red clay	1	6
	6	9

North of Market Weighton and just south of the railway the base of the Red Chalk, here very conglomeratic, can be seen resting on the clays and ironstone of the Lias.

Many small exposures occur by Millington Springs and in

[1] "On the Lower Beds of the Upper Cretaceous Series in Lincolnshire and Yorkshire," Quart. Journ. Geol. Soc., vol. xliv. p. 333.

[2] Proc. Geol. Assoc., vol. v. p. 247 (1878).

[3] Quart. Journ. Geol. Soc., vol. lii., p. 179 (1896).

[4] Geol. Mag., Dec. 2, vol. x, p. 218.

Deepdale, also at Grimsthorpe and by Great Givendale. At the last place, in a plantation near the church, Prof. J. F. Blake saw in 1874 an exposure which showed the following succession:—

White chalk,
Red chalk,
Conglomerate of rounded black stones,
Variegated sandstone,

He does not give thicknesses. Mr. Hill, writing of this district, says the basement-bed is very conglomeratic, "large fragments of ironstone of oolitic structure occurring in it." Mr. Blake also mentions a noteworthy exposure at the head of Scottendale, east of Kirby Underdale, and this was described by Mr. Lamplugh in 1896 as follows[1]:—

		Feet.	*in.*
Hard pinkish and yellowish nodular chalk		2	0
Red Chalk	Deep red and yellowish nodular chalk, about	2	0
	Soft shaly red chalk	0	3
	Hard gritty nodular red chalk	1	0
	Yellow clayey marl with ferruginous grains	1	0
Coarse pebbly ferruginous sand of a deep-brown colour, with pebbles of oolitic ironstone, phosphatic nodules and small pebbles of lydite and quartz, up to		6	0

Belemnites minimus was abundant throughout the Red Chalk, and of the sand below he remarks that it so closely resembles the Lincolnshire Carstone that it may safely be correlated with that bed; it must be remembered, however, that at Audleby in Lincolnshire the upper part of the Spilsby Sandstone is coarse and pebbly.[2]

Another exposure occurs in Garrowby Park, about half a mile east of the Hall, where Mr. Hill saw:—

	Feet.
Inoceramus Beds, grey, gritty chalk	$3\frac{1}{2}$
Sponge Bed, very hard yellowish-red chalk with smooth clean fracture	1
Red Chalk, smooth at the top, nodular below, the lower part full of quartz grains	4

Mr. Blake says "at a little lower level are great blocks of conglomerate, and below that a sandpit." Thus the succession would seem to be like that at Great Givendale.

From this point the Red Chalk thins more rapidly, till round Acklam and Leavening it is only from two to three feet thick.

It is well exposed above a mass of Chalk which has slipped from its place on the hill-side near Leavening. Here much of the Lower Chalk is seen with a foot of reddish-yellow limestone at the base; below this is Red Chalk, pale red at the top, darker red below, full of quartz grains throughout and containing many *Belemnites minimus*. It is only two feet thick, but passes down into a layer of yellowish material full of coarse quartz sand,

[1] Quart. Journ. Geol. Soc., vol. lii. p. 188.
[2] See Mem. Geol. Survey, Explanation of Sheet 86, p. 108 (1890).

dark-coloured oolitic grains, and small lumps of oolitic ironstone. This layer is not more than six inches thick, and rests on Oxford Clay.

On the south-west side of the outlier on which Wharram Grange Farm stands, Mr. Hill found an exposure which appears to exhibit the most attenuated form of the Red Chalk. Its thickness is not more than 18 inches, and the deep-red colour is gone. The bed consists of a very hard, dirty yellow conglomeratic limestone, which is here and there streaked or mottled by rusty-brown stainings. It is full of large fragments of oolitic ironstone with many quartz and separate oolitic grains. It is also very fossiliferous, containing *Belemnites minimus, Terebratula biplicata, Ter. capillata,* and *Cardiaster suborbicularis* in some abundance; also badly preserved fragments of Ammonites, which seem to belong to *Ammonites auritus* or its varieties.

From this locality the Red Chalk appears to thicken southwards, northwards, and eastwards, for Prof. Blake records a section near Wharram Station a little more than a mile to the E.S.E., where there is two feet of yellowish-red chalk passing down into 1½ feet of argillaceous and ferruginous grit. Again, only five miles to the N.N.E., on Scragglesthorpe Brow, Mr. Fox-Strangways has seen 10 feet of Red Chalk exposed.

At the time of Mr. Hill's visit it was difficult to estimate the thickness at the latter place, but he describes it as resembling the Red Chalk of Speeton rather than that along the western border of the Wolds; being smoother, deep-red in colour, and not containing any mineral fragments, except perhaps at the base, which was not exposed.

Rather more than five miles to the east of this, at East Heslerton, Mr. Fox-Strangways records a well-boring which passed through the following beds [1]:—

	Feet.
Chalk - - - -	50
Red clay - - -	25
Black clay	92

He has no doubt that the "red clay" is the Speeton type of "red chalk," *i.e.,* red argillaceous marl.

Between this and Speeton no good sections are now open, but Messrs. Young and Bird describe a section at Knapton in terms which leave no doubt that there was here a passage from the Speeton Clay into red marl, as at Speeton.[2]

The Red Marl of Speeton has been described by many writers, notably by Prof. Wiltshire, Prof. Blake, and Mr. W. Hill; and its junction with the beds below has been noticed more particularly by Mr. C. J. A. Meyer in 1869 and by Mr. G. W. Lamplugh in 1889.

In 1869, Mr. Meyer briefly described [3] a section seen by him

[1] The Geology of Scarborough, Mem. Geol. Survey, 1880, p. 26.
[2] See "Geological Survey of the Yorkshire Coast," 2nd Edition (1828), p. 62, and G. W. Lamplugh in Quart. Journ. Geol. Soc., vol. lii. p. 185.
[3] Geol. Mag., vol. vi. p. 13.

in September, 1868, on the south side of Speeton Beck, which exposed the junction-beds and showed a complete passage downward from the red marl into the black clays. His description may be summarised as follows:—

"Red Chalk" with *Terebratula biplicata*, *Belemnites miminus*, *Vermicularia Phillipsii*, and other fossils, 4 feet.
Pale reddish clay, with *Inoceramus sulcatus* and *Bel. miminus*, about 2 feet, passing down into black clays with *Bel. semicanaliculatus*, seen for 5 feet.

Mr. Hill in 1888[1] "was unable to find the actual junction of the Red Chalk with the Speeton Clay."

It was reserved for Mr. Lamplugh in 1889[2] to settle the question and to confirm Mr. Meyer's observation by recording several exposures where the passage-beds were visible in that year. The sequence seen by Mr. Lamplugh along the cliff foot about 350 yards from Speeton Gap was:—

	Ft.	in.
Red Chalk, slipped and crushed - - - - -	—	—
Mottled marly shale with bright-green streaks -	2	0
Dull reddish clay with yellow and green streaks - -	0	6
Streaked brown gritty marl - - - - - - -	0	3
Bright yellow and green seam with eroded nodules -	0	3
Striped brownish shaly clay - - - - - - -	0	6
Black clay seen for about - - - - - - -	3	0
	6	6

The black clay contains *Bel. semicanaliculatus* only; from the beds above he obtained Gault fossils, namely:—

Belemnites minimus and vars.
Inoceramus concentricus.
Inoceramus sulcatus.
Inoceramus sp. (a larger form).
Ostrea sp.
Avicula rauliniana ?
Nucula pectinata ?
Lingula sp.
Vermicularia elongata (Bean, M.S.).
Fish scales

"In this section," says Mr. Lamplugh, "the green and yellow gritty bed with nodules forms a very striking and distinct horizon, . . . being full of nodules that look as though they might be derivatives and frequently present a curiously pitted and partially decomposed surface, as if through erosion. These are often coated thickly with gritty green matter (probably glauconite) and sometimes form a centre from which springs a mass of radiating crystals (selenite) which completely surrounds the nodule in a layer from an inch to three inches thick."

Of the overlying marls he says they seem to contain "much extraneous gritty matter, and all are streaked and dabbled with glauconite. In the dull red band small smooth pebbles (lydites) not larger than duck-shot have been observed."

"The possibility of a representative of the Gault other than the Red Chalk existing at the top of the Speeton Clay has been once or twice suggested, but has been regarded as untenable. In these

[1] Quart. Journ. Geol. Soc., vol. xliv., p. 338.
[2] Quart. Journ. Geol. Soc., vol. xlv., p. 603.

beds, however, we have probably a representative of the Lower, while the Red Chalk itself may represent the Upper division of the Gault."

Above these variegated marls, there is about 30 feet of deep-red marly chalk. The lowest ten feet are seldom seen, being generally covered by slips, but Mr. W. Hill informs me that this part has a somewhat bedded appearance, though in places decidedly nodular.

The central part is more distinctly nodular, the nodules being simply potato-like lumps of a harder and more calcareous material than the soft marl in which they lie. There are also some layers in which the nodules are greyish-white. In the upper part, this nodular character gradually dies away, and the uppermost four feet consist of a smooth, firm, or moderately hard marl, rather paler in colour than that below.

Belemnites are most abundant in the lower part, are seldom seen in the middle, but occur occasionally in the top fout feet.

LIST OF FOSSILS FROM THE RED CHALK OF YORKSHIRE.

This list has been compiled from the following sources :—

1. Phillips' Geology of Yorkshire. Part I., third edition. (1875.) Lists of fossils.
2. Wiltshire, The Red Chalk of England. Proc. Geol. Assoc. (separate paper), and Geologist, vol. ii. p. 261. On the Red Chalk of Hunstanton. Quart. Journ. Geol. Soc., vol. xxv. p. 185.
3. J. F. Blake, Geol. Mag., Dec. 2, vol. i. p. 362, and Proc. Geol. Assoc. vol. v., p. 232.
4. Ch. Barrois, Recherches sur le Terr. Cret. Sup. p. 191. (1876.)
5. W. Hill, Quart. Journ. Geol. Soc., vol. xliv., p. 347.

	Yorkshire Wolds.	Speeton.
Mollusca.		
Ammonites auritus ?, *Sow.*	x	–
„ Deshayesi, *Leym.*	x	–
„ rostratus, *Sow.*	x	–
Belemnites minimus, *List.*	x	x
Nautilus elegans, *Sow,* (? albensis).	x	–
„ sp.	x	–
Avicula gryphæoides, *Sow.*	x	x
Exogyra rauliniana, *d'Orb.*	–	x
Ostrea canaliculata, *Sow.*	–	x
„ vesicularis, *Sow.*	–	x
„ vesiculosa, *Sow.*	–	x
Pecten Beaveri, *Sow.*	x	–
Plicatula pectinoides, *Sow.*	x	–
Inoceramus Crispi, *Mant.*	–	x
„ sulcatus, *Park.*	x	x
„ tenuis, *Mant.*	–	x
Spondylus gibbosus, *d'Orb.*	–	x
„ striatus ?, *Sow.*	–	x

——	Yorkshire Wolds.	Speeton.
Brachiopoda.		
Kingena lima, *Defr.*	x	x
Rhynchonella lineolata, *Phil.*	–	x
„ sulcata, *Park.*	x	x
„ latissima (? sulcata).	x	–
Terebratula biplicata, *Sow.*	x	x
„ capillata, *d'Arch.*	x	x
„ semiglobosa, *Sow.*	x	x
„ sulcifera ? *Morris.*	x	x
Terebratulina triangularis, Eth.	x	x
„ striata, *Wahl.*	–	x
Polyzoa.		
Proboscina dilatata, *d'Orb.*	–	x
Ceriopora spongitis, *Goldf.*	–	x
Crustacea.		
Pollicipes unguis, *Sow.*	–	x
Cytherella ovata, *Röm.*	–	x
Echinodermata.		
Cidaris gaultina, *Forbes.*	–	x
Torynocrinus rugosus, *Seeley.*	x	–
Holaster suborbicularis, *Defr.*	x	x
Pentacrinus Fittoni, *Aust.*	–	x
Annelida.		
Serpula concava, *Sow.*	–	x
„ umbonata, *Sow.*	–	x

The *Foraminifera* found in the Red Chalk of Speeton have been identified and catalogued by Messrs. Burrows, Sherborn, and Bailey in the Journ. Roy. Micr. Soc. for 1890, p. 549, and their list is embodied in our general list (p. 481).

Mr. F. Chapman has compared the Foraminifera found in the Red Chalk of Yorkshire and Norfolk with those of the Folkestone Gault and the Chalk Marl of Folkestone. He records 86 species from the Red Chalk. "Of these, 52, or a little more than 60 per cent., have been found in the Gault of Folkestone. In the Lower Gault 38 Red Chalk forms occur; whilst in the Upper Gault (zones VIII, to XIII,) we find 48 species common to this and the Red Chalk; or 44 per cent. and nearly 56 per cent. respectively."

Of the 86 Red Chalk species only 25 were found in Bed II. of the Chalk Marl in Eastwear Bay, and Mr. Chapman concludes that the conditions under which the Red Chalk was deposited were similar to those prevailing during the formation of the Upper Gault at Folkestone. He adds, "there is a marked absence of shallow water and coarsely-grown arenaceous Foraminifera in the Red Chalk, quite unlike the assemblage found in the Chalk Marls."

It is interesting to find that the foraminiferal fauna of the Red Chalk links it more closely with the Upper Gault of Folkestone than with the Chalk Marl of that locality, but we feel bound to point out that Folkestone is a long way from Norfolk, and the number of species common to the Red Chalk and the beds which immediately overlie it may be greater than the number common to the former and the Chalk Marl of Kent. We hope Mr. Chapman may some day be able to compare the Foraminifera of the Red Chalk with those of the Gault and of the Lower Chalk of Norfolk.

CHAPTER XXIII.

CHEMICAL ANALYSES OF GAULT CLAYS, RED CHALKS, AND MALMSTONES.

Analyses of Gault Clays.

Very few analyses of Gault clays have hitherto been published, but the following pages contain the particulars of no less than 24 separate analyses. Some of these have been collected from various publications; some have been recently put at our disposal, and four have been specially made for us, by our friend Prof. J. B. Harrison, Chemist to the Colonial Government of British Guiana, from samples which we sent out to him.

Of the analyses which follow, some were made for commercial purposes only and do not take note of the minor and less important ingredients, such as Phosphoric Acid, Sulphuric Acid and the Alkalis; others, such as those by Prof. Harrison, Messrs. Paine and Way, and Mr. P. G. Sanford, are much more complete.

Analyses of phosphatic nodules from the Gault will be found in the Chapter on Economics.

Two partial analyses of samples from the Gault of Folkestone were made by Mr. W. H. Hudleston for Mr. F. G. H. Price, and published by the latter in his paper on the Gault of Folkestone.[1] The first is from the Lower Gault (Bed II.) and the second from the Upper Gault (Bed XI.).

Dried at 100° C.	A.	B.
Water and organic matter	8·25	6·75
Carbonate of lime - - - - - -	8·61	26·45
Silica, silicates, oxides of iron,[2] pyrites, &c.	81·93	65·95
Chloride of sodium - -	—	
Carbonate of magnesia (traces) -	—	·81
Sulphuric acid - - - -	1·21	
Phosphoric acid (traces) - - - -	—	·04
	100·00	100·00

Of the tabular ironstone found in Bed III. Mr. Hudleston reported that it was "a clay ironstone free from grit." The bulk of the mass consists of of pulverulant carbonate of lime, ferrous carbonate, and extremely fine particles of clay, with about 2 per cent. of pyrites.

The amount of metallic iron (principally as protoxide)	29·40
Add for iron in combination with sulphur, say -	1·00
	30·40

[1] Quart. Journ, Geol. Soc., vol. xxx. p. 342.
[2] Metallic iron 4·25 per cent. in A, 2·55 per cent. in B.

The following are analyses of the Upper Gault clays in the Medway Valley; No. 1 being an analysis by Dr. A. Voelcker of a specimen of clay from the pit of the West Kent Cement Works, Aylesford.[1] No. 2 is of the Gault used for brickmaking at Burham.[2] No. 3 is of a "Medway Gault," locality not specified.[3]

——	1	2	3
Water	4·09 (Water and Organic matter)	6·68	
Organic matter		5·01	
Carbonate of lime	21·97	18·91	24·95
Oxide of iron	4·03	5·00	6·07
Alumina	12·69	20·42	16·06
Magnesia and alkalis	·88	·45	6·18[4]
Insoluble siliceous matter	56·34	42·92	46·61
	100·00	99·39	99·87

For the following analyses of the Gault clays dug at Burham we are indebted to the Chairman and Manager of the Burham Lime and Cement Company (7, Nicholas Lane, Lombard Street). The analyses were made by Messrs. Stanger and Blount, of Broadway, Westminster. The samples supplied were from the beds known in the clay pit as I. (Top white), II. (Bottom white), III. (Top blue), and IV. (Bottom blue). Nos. I. and II. are from the light-grey clays at the top of the pit (*see* ante, page 89), and Nos. III. and IV. are from the blue clays, the last being presumably from near the bottom of the section. The samples were dried at 212° F.

——	I.	II.	III.	IV.
Insoluble matter (silicates)	54·82	51·36	57·34	66·39
Ferric oxide and Alumina	2·55	4·66	3·80	4·12
Lime	20·21	21·68	17·37	11·12
Magnesia	0·29	0·39	0·47	0·63
Carbonic anhydride*	15·26	16·12	13·75	8·57
Combined Water and Loss	6·87	5·79	7·27	9·17
	100·00	100·00	100·00	100·00
* Corresponding to Calcium carbonate	34·68	36·34	31·25	19·48

The amount of hygroscopic water present in the moist sample before they were dried was found to be as follows:—

I.	II.	III.	IV.
25·69	23·82	27·01	24·28

[1] Given by Mr. A. E. Carey, Proc. Inst. Civ. Eng., vol. cvii. p. 41 (1892).
[2] From Notes on Building Construction, Rivingtons, p. 88.
[3] J. L. Spoor. Off. Loc. Guide. Industr. Sect. 1889, p. 216.
[4] This amount is entered as alkalis, but seems so large that it may include water and organic matter which are not mentioned.

It will be seen that the first three, which are all from the upper part of the pit, all contain over 30 per cent. of carbonates, while the lowest clay has only about 20 per cent.

The following samples of the highest part of the Gault were kindly analysed for us by Prof. J. B. Harrison, F.G.S., Government Chemist at Georgetown, British Guiana. By his method of treating siliceous material,[1] the amount of soluble colloid silica is determined in a manner which prevents its including such silica as might be set free from decomposable silicates in the ordinary method of analysis, and the silica present as quartz sand is also separately determined. Thus his analyses give a much more complete idea of the real mineral composition of a clay.

No. 1 is a dark-grey marl near the base of Bed 13, Folkestone.

No. 2 is a grey marl overlying No. 1 at Folkestone.

No. 3 is from the top of the blue-grey Gault at Aylesford.

No. 4 is from the pale-grey Gault above No. 3 at Aylesford.

—	1.	2.	3.	4.
Organic matter and combined water	3·35	2·33	5·18	3·51
Colloid silica	8·41	6·12	7·60	7·58
Carbonate of lime	29·20	22·72	32·29	38·08
Sulphate of lime	0·15	0·07	0·08	0·08
Phosphate of lime	0·20	—	0·15	trace
Carbonate of magnesia	2·49	6·21	0·66	trace
Silica as quartz and mica	12·82	3·06	10·36	4·71
Silicates in the form of clay	43·38	59·49	43·78	46·04
	100·00	100·00	100·00	100·00
The silicates showed the following composition :—				
Combined silica	23·13	34·03	18·52	26·07
Alumina	10·68	17·28	15·60	11·33
Protoxide of iron	0·75	0·38	0·56	0·37
Peroxide of iron	5·03	5·08	3·98	4·60
Lime	—	—	—	0·77
Magnesia	0·61	0·09	1·77	1·22
Potash	1·77	1·14	1·91	0·96
Soda	1·41	1·49	1·44	0·72
	43·38	59·49	43·78	46·04

Prof. Harrison remarks, "the argillaceous constituents are certainly not of the nature of true clay or kaolin, in fact little such clay appears to be present in the samples. They all seem to belong to clays which may be regarded as the first products of the decomposition of felspars. I am inclined to consider that the ferric oxide is in the state of silicate, replacing an equivalent amount of alumina."

In a later note he says, "there appear to be two classes of kaolins, the ordinary kaolin containing from 43 to 47 per cent. of silica, and another containing from 73 to 81 per cent. Probably most naturally occurring clays are mixtures of these two kaolins in varying proportions, the former usually predominating, and mixed with varying amounts of quartz sand, iron oxides, &c."

It will be seen that the amount of silica present as fine sand varies very much; "muscovite mica occurred with this and proved highly resistant to the acid and alkali."

It is interesting also to find that they all contain soluble colloid silica to a considerable amount, but it must be in a state of minute division, for Mr. Hill reports that he could not recognise any globular colloid silica in these clays under the microscope.

The proportion of carbonates also is high, the Folkestone marls having

[1] Described in Quart. Journ. Geol. Soc., vol. xlviii., p. 182.

from 29 to 31·6 per cent., and those from Aylesford containing from 33 to 38 per cent.

The following analysis of Gault from Dunton Green, near Sevenoaks, Kent, dried at 100° C.,[1] was made by Mr. P. Gerald Sanford, F.C.S. :—

		composed as below.
Insoluble residue	65·01 =	
Ferric oxide, Fe_2O_3	7·92	2·05
Alumina, Al_2O_3	3·4	15·41
Oxide of Manganese, MnO	trace	—
Lime, CaO	5·9	·88
Magnesia, MgO	·75	·24
Sodium Chloride, NaCl.	·05	—
Phosphoric Acid, P_2O_5	·11	—
Sulphuric Acid, SO_3	·19	—
Carbonic Acid, CO_2	6·09	—
Potash and Soda, K_2O and Na_2O	·07	—
Combined Water	10·48	—
Silica, SiO_2	—	46·43
	99·97	65·01

In this analysis there is rather more carbonic acid than is required to combine with the lime and magnesia, and if the carbonic anhydride was correctly estimated, we can only suppose that a little of the iron exists as protoxide in the form of carbonate of iron.

Messrs. Paine and Way made analyses of three samples of Gault from near Farnham, which they term respectively Lower, Middle, and Upper Gault, meaning no doubt that they were taken from the lower, middle, and upper portions of the clays which underlie the soft malmstone (*see* p. 108). They are interesting as showing that there is little Carbonate of Lime in the Gault of this district, which is mainly Lower Gault, and that it contains a considerable amount of soluble silica, but the method of analysis does permit of the separation of the silica present as fine quartz sand from that present in a state of combination. The figures given are as follows :—

——	Lower.	Middle.	Upper.
Combined water, with a little organic matter	7·68	6·38	5·47
Soluble in dilute acids :—			
Silica	16·65	26·89	24·80
Carbonic Acid	—	3·13	—
Sulphuric Acid	trace	·03	trace
Chlorine	·03	trace	·03
Lime	·66	5·34	·75
Magnesia	·77	·35	·26
Potash	·66	·74	·35
Soda	·15	·31	·16
Oxides of Iron	3·16	7·25	4·56
Alumina	1·24	6·50	·94
Insoluble in dilute acids :—			
Lime	trace	1·61	1·29
Magnesia	trace	·91	·82
Potash	1·53	2·16	1·57
Soda	1·90	·42	·64
Alumina and a little oxide of iron	19·06	7·88	11·29
Silicic Acid and Sand	46·51	29·83	47·07
	100·00	100·00	100·00

[1] Geol. Mag., Ser. 3, vol. vi. p. 456 (1889).

The following is an analysis by Dr. A. Voelcker, of a specimen of Gault from Glynde in Sussex [1]:—

Water of combination and organic matter	3·43
Oxide of iron	4·33
Alumina	13·13
Lime	10·58
Carbonic acid, alkalis, &c.	11·73
Insoluble siliceous matter	56·80
	100·00

As the CO_2 was not separately determined the exact amount of carbonate of lime cannot be calculated, but if we assume that all the lime was combined with carbonic acid, as is probable in this case, the amount of calcium carbonate would be 18·89 per cent.

The highly calcareous marl which forms the Upper Gault of Buckinghamshire and part of Bedfordshire has been described on p. 286. Similar pale-coloured Gault marl occurs in Norfolk near Stoke Ferry, and when Mr. W. Hill and I were investigating the characters and stratigraphical relations of this Norfolk Gault,[2] we desired to compare its chemical composition with that of the Upper Gault of Bucks. For this purpose an analysis of a sample of Gault marl from Fancourt was made for us by Mr. W. D. Severn in the South Kensington Laboratory with the following result. The sample having been treated with *boiling concentrated* hydrochloric acid, there was found :—

Moisture at 100° C.		2·00
Insoluble residue		38·21
Soluble	Lime	31·11
	Carbonic Acid	22·39
	Phosphoric Acid	·09
	Iron (as FeO)	2·00
	Alumina	3·90
		99·70

If all the lime in this is supposed to be united with Carbonic Acid, there would be 53·50 of calcium carbonate, but 22·39 parts of carbonic acid require only 28·48 parts of lime, so the actual amount of calcium carbonate indicated by this analysis is only 50·87. This, however, is a very high proportion, a little more than half the mass of the deposit being carbonate of lime. The remainder of the lime (2·63 per cent.) probably exists in combination with alumina as a silicate, and was set free by the action of the boiling hydrochloric acid.

The Lower Gault of Bedfordshire and Cambridgeshire is also more calcareous than the Lower Gault of more southern counties, as the two following analyses will show.

The first is an analysis of Gault dug at the Arlesey Cement Works near Hitchin, and for this I am indebted to Mr. J. Noel Shillito, the manager of the company. It is as follows :—

Combined water and organic matter	9·51
Carbonic Acid	13·79
Lime	17·54
Alumina	14·07
Iron (as Fe_2O_3)	2·41
Silica	42·46
	99·78

The amounts of lime and carbonic acid are here exactly proportioned to their combining weights, and are equivalent to 31·33 per cent. of

[1] Given to Mr. Whitaker by Mr. A. E. Carey, Proc. Inst. Civ. Eng., vol. cvii., p. 41 (1892) and letter.

[2] See Quart. Journ. Geol. Soc., vol. xliii. p. 586.

carbonate of lime. The amount of Alumina is not large, and the silica must be partly in the state of finely divided quartz sand.

Mr. Shillito has kindly checked this analysis so far as the amount of calcium carbonate is concerned by submitting a sample of the Gault taken from the neighbouring brickyard to the calcimeter on the premises of the Cement Works, this method showing 26·26 per cent. of calcium carbonate. It may be taken as certain, therefore, that the upper part of the Lower Gault at Hitchin contains from 26 to 31 per cent. of carbonate of lime.

The following is an analysis of Gault clay from Hinxworth, in Bedfordshire, by Prof. Way, quoted by Mr. J. B. Denton[1]:—

Moisture and organic matter	5·01
Sand	·66
Clay	63·26
Carbonate of lime	31·07
	100·00

The sample appears to have been taken from the Gault immediately underlying the Cambridge greensand or Coprolite bed which was then (1862) being worked at the locality. Mr. Denton describes it as "remarkably stiff and tenacious, though impregnated with lime from its proximity to the Chalk." It is doubtful, however, whether the proximity of the Chalk Marl has anything to do with the proportion of carbonate of lime in the Gault here, for this closely corresponds with the amount found in the Gault of Arlesey, and is much less than that which exists in the Upper Gault of Fancourt west of Harlington.

The following analyses have been made of the Upper Gault Marls of Norfolk.

No. I. is that of a grey marl taken from a depth of 5 feet in the boring at Roydon mentioned on p. 300, analysed by Mr. W. D. Severn.

The other three were red marls and were analysed by Dr. W. Johnstone, No. II. being from Grimston, No. III. from Roydon, and No. IV. from the boring at Dersingham (*see* p. 301).

——	I.	II.	III.	IV.
Silica and silicates (insoluble)	25·55	22·60	24·13	25·70
Carbonate of lime	66·31	69·50	64·46	64·49
Carbonate of magnesia	·46	·90	·90	1·32
Sulphate of lime	—	·66	·36	·33
Peroxide of iron	·81	3·40	6·00	4·16
Alumina and phosphoric acid	3·33	1·60	·90	·80
Organic matter and water	1·85	1·34	3·25	3·20
	98·31	100·00	100·00	100·00

It will be seen that these are highly calcareous marls, and they are associated with a limestone which was also analysed by Dr. Johnstone with the following result:—

Insoluble silica and silicates	6·64
Carbonate of lime	89·46
Carbonate of magnesia	·18
Sulphate of lime	1·32
Manganese	·40
Alumina	1·40
Peroxide of iron	1·10
	100·50

[1] Proc. Inst. Civ. Eng., vol. xxi. p. 51

Analyses of Red Chalk.

Several analyses of the Red Chalk of Hunstanton have been published, and six of these have been collected and printed in the "Geology of the Borders of the Wash."[1] None of them however are very satisfactory and they differ very much from one another, partly because they have been made by different methods, and partly because the samples analysed were taken from different parts of the red stratum.

Prof. A. H. Church in 1863[2] analysed some of the dark red nodular portions of the rock and also some of the light red parts. He says, "the hard nodules contained as much as from 31·2 to 36·9 per cent. of anhydrous sesquioxide of iron, while the pale red varieties . . . . contained no more than from 12·73 to 4·1." He gives a complete analysis of the dark red nodules, but as this shows 16·41 per cent. of water it was evidently not dried, and consequently his figures do not accurately represent the proportions of the mineral ingredients of the rock. Thus supposing half the quantity of water to be driven off at a temperature of 100° C. the proportion of ferric oxide would amount to 40 per cent. instead of 36·9 as given.

Dr. W. Johnstone also analysed some of the hard red nodular lumps about the year 1884 with the following result:—

Lime	22·839
Carbonic Acid	18·922
Alumina	1·214
Phosphoric Acid	·336
Peroxide of Iron	42·683
Oxide of Manganese	·758
Oxide of Copper	·034
Trioxide of Arsenic	1·286
Sulphuric Acid	·342
Chlorine	1·023
Silica	8·425
Magnesia	·708
Water	·120
Organic Matter	·323
Alkalies	·951
	99·964

This sample had evidently been dried at a high temperature, and the amount of peroxide of iron found confirms Prof. Church's analysis. If the magnesia exists as a carbonate there is 1·486 of that mineral, and if the phosphoric acid is combined with lime there is ·620 of the phosphate. The rest of the lime combined with carbonic acid will amount to 40·327 per cent. of carbonate of lime. This is small compared with analyses of the higher pink or light red portion of the rock, which yields from 80 to 83 per cent. of calcium carbonate.

The following analyses were carried out for Prof. Liveing by Mr R. A. Berry, F.I.C., and are published by their kind permission, with the accompanying notes by Mr. Berry :—

"Professor Liveing having suggested that it was probable that

[1] Mem. Geol. Survey, 1899, p. 38.
[2] Quart. Journ. Chem. Soc., N. Ser., vol. i., pp. 79–86

the Red Chalk contained a sensible amount of phosphates and that it would be interesting to determine this amount and to find in what state of combination they existed, I obtained and analysed three samples from Hunstanton and three from Candlesby in Lincolnshire.

"In the analyses of Red Chalk published prior to 1896 no mention is made of the existence of phosphates, but Prof. H. G. Seeley, writing in 1864,[1] stated that the concretions in the middle part of the rock are phosphatic, and that 'one of them, analysed by Professor Liveing, yielded 11 per cent. of that substance.'

"The samples were prepared for analysis by first breaking them up in an iron mortar and picking out the fossils and the large quartz-grains. The crushed chalk was then run through a piece of fine muslin and ground to an impalpable powder in an agate mortar. It was next dried at 120° C. in an air oven for four hours, and finally placed in a well-stoppered bottle for the analysis. I made a complete analysis of each sample, with a duplicate, by the ordinary method for analysing limestones. All the phosphates went into solution as ferric phosphates; to find, therefore, how much existed originally as calcium phosphate I treated a portion in very fine powder with a cold dilute solution of acetic acid, allowed the acid to remain in contact for ten minutes, then filtered, and analysed the filtrate. The residue left on the filter was dried and weighed, dissolved in hydrochloric acid, evaporated to dryness, and filtered; the filtrate was then analysed.

"The following are the complete analyses of the three samples from Hunstanton:—

——	Lower (red).[2]	Middle (dark red).	Upper (light red).
Insoluble matter	10·48	5·97	18·7
Colloid silica	3·9	3·21	3·17
Calcium phosphate	·85	1·65	·32
Ferric phosphate	1·77	2·44	·74
Ferric oxide	5·57	4·62	6·53
Alumina	1·44	1·94	1·25
Manganese dioxide	·5	1·3	·88
Calcium carbonate	69·1	74·	64·45
Magnesium carbonate	2·36	1·93	1·44
Magnesium chloride	·21	—	—
Lime	2·31	2·14	1·46
Moisture	·65	·2	·45
	99·14	99·40	99·39

[1] Quart. Journ. Geol. Soc., vol. xx., p. 328.

[2] It must be remembered that large quartz-grains are abundant in this portion, and that these were picked out before analysis; still it is curious that the sample should have contained less fine siliceous matter than that from the highest bed.—A. J. J.-B.

"At Candlesby in Lincolnshire the Red Chalk is about 12 feet in thickness, and the division into three portions is still more apparent, but they are not of equal thickness as at Hunstanton. There is at the top about 3 feet of what is called pink chalk; the next or middle portion is much harder and darker in colour, but is only about 1 foot thick; the lower portion of the rock (7 or 8 feet) is of a blood-red colour, and is soft and crumbly. This lower part is separated from the middle one by a thin layer of putty-like marl, of dark red colour and about 1 inch in thickness.

"Samples of each part were analysed in the same manner, and the results were as below:—

——	Lower (dark red).	Middle (red).	Upper (pink).
Insoluble matter	15·35	6·81	4·26
Colloid silica	2·65	·56	·90
Calcium phosphate	·19	·34	·39
Ferric phosphate	·34	·68	—
Ferric oxide	3·12	1·04	1·34
Alumina	·74	·32	·30
Manganese dioxide	1·13	·47	·69
Calcium carbonate	71·68	87·34	90·16
Magnesium carbonate	2·03	1·10	1·72
Lime	1·78	—	—
Moisture	·37	·42	—
	99·38	99·08	99·76

Commenting on these results, Mr. Berry says, "In four out of the six analyses there is some lime remaining uncombined, but this, I think, is due to the decomposition of the alkaline silicates present, as the samples give an alkaline reaction with red litmus paper when moistened. It is also clear from the correlative variation of the lime and the colloid silica that there is a connection between them.

"According to the above determinations both calcium phosphate and ferric phosphate appear to exist in every case except one, but in varying quantities; the largest amount occurs in the dark-red sample from Hunstanton, this yielding 4·09 per cent. of phosphates as compared with 1·06 in the top bed. At Candlesby also the greatest amount—1·02 per cent.—occurs in the dark-red bed. The amounts found in the Lincolnshire beds are far less than those in the Hunstanton beds, but if we compare the thickness of the Red Chalk at the two localities, and proportion the phosphates accordingly, the total amounts would be nearly the same, viz., 6·43 and 7·77.

"This seems to show that the amount of phosphates present in solution or otherwise during the deposition of the bed at the two localities was nearly the same, but that at Candlesby (and

throughout Lincolnshire) there was a more abundant growth of calcareous organisms, so that the Red Chalk of that county more approaches a chalk in composition.

"The ferric phosphate always occurs in greater quantity than the calcium phosphate, and it appears to me rather strange that any of the latter should exist at all in contact with so much iron. From its presence one would almost conclude that the phosphate was first deposited as calcium phosphate and that the iron was introduced afterwards, for it is scarcely probable that the formation of both calcium and ferric phosphates should be in progress at the same time. The bed may possibly have derived its phosphates from a previously formed deposit, which was partly decomposed and remade. However this may have been, the results seem to show that the phosphate was deposited as calcium phosphate, and that the replacement by the iron took place afterwards.

"The colour of the bed is well known to be due to limonite (hydrated peroxide of iron), but the amount of ferric hydrate present does not seem to vary in proportion to the richness of colour so much as one would expect."

Before the above analyses by Mr. Berry were placed at my disposal I had asked Dr W. Pollard to make partial analyses of some samples of Red Chalk from Lincolnshire, because till that time only one analysis of such chalk from that county had been published. This analysis was made by Mr. Meaburn Staniland, and was published in the memoir on the Geology of East Lincolnshire (p. 33); it is as follows:—

Insoluble in Hydrochloric Acid:		
Silica	4·49	
Peroxide of Iron	1·56	
		6·05
Soluble portion:		
Lime	49·36	
Peroxide of Iron	1·96	
Magnesia	1·10	
Carbonic acid	41·20	
Phosphoric acid	trace	
Moisture	1·08	
		94·70
		100·75

This indicates a percentage of about 88 of calcium carbonate.

The samples analysed by Dr. Pollard were obtained for us by Mr. M. Staniland from exposures at Langton. Sample 1 is from a layer of dark-red shale below No. 2; Sample 2 is a red chalk

two feet above the base, these are both from Langton sand pit described on p. 306; Sample 3 is from two feet below the white chalk in Langton Chalk-pit. Respecting his methods of analyses Dr. Pollard writes:—"In the analyses marked A the sample was treated with dilute Hydrochloric acid (about 5 per cent of H Cl.) and gradually heated to boiling. The residue contained most of the iron and alumina.

In the analyses marked B the sample was treated with dilute Hydrochloric acid, boiled to remove carbon di-oxide, evaporated on the water bath to dryness; the mass was then treated with strong Hydrochloric acid and again evaporated, then taken up with a few drops of Hydrochloric acid and hot water and filtered. Practically all the iron was then got into solution.

The term "insoluble residue" is useless and misleading unless the conditions under which it was determined are stated. It will be seen that by treatment with strong Hydrochloric acid almost all the iron oxide was dissolved together with alumina and more Magnesia. The increase of Magnesia is probably due to the decomposition of silicates.

The Carbon di-oxide was determined by direct weighing. Small quantities of Phosphoric acid and of Manganese oxide were found in all three samples but none were estimated.

—	No. 1 (lowest).		No. 2 (higher).		No. 3 (highest).	
	A.	B.	A.	B.	A.	B.
Insoluble residue	50·3	39·2	23·0	18·6	8·7	7·4
Dissolved:						
Ferric oxide	4·7	10·6	1·1	4·4	0·9	1·4
Alumina		5·1		1·2		0·3
Lime	20·5	20·4	39·9	39·8	49·5	49·5
Magnesia	0·6	1·0	0·5	0·9	0·4	0·7
Carbonic acid	15·7	15·7	31·0	31·0	38·9	38·9
Water at 105°	4·0	4·0	2·0	2·0	0·5	0·5
" above 105°	2·7	2·7	1·5	1·5	0·9	0·9
	98·5	98·7	99·0	99·4	99·8	99·6

Dr. Pollard adds that the amount of silica in No. 1 is 31·5 per cent., in No. 2, 13·7 per cent., and in No. 3, 5·5 per cent.

Assuming that all the magnesia in the A columns is in the form of a carbonate, and deducting small proportionate amounts for this from the carbonate acid figures, it would appear that the amounts of Calcium carbonate in the three samples are respectively 34·3, 69·3, and 87·5. The third and highest sample appears to agree very closely in composition with that analysed by Mr. Staniland.

Of the red marly chalk of Speeton two analyses were made for

Mr. W. Hill by Mr. J. W. Knights of Cambridge and are as follows[1]:—

———	Lower part.	Upper part.
Insoluble siliceous matter	42·40	24·60
Oxide of iron and alumina	10·20	4·80
Carbonate of lime -	45·	59·60
Carbonate of magnesia	1·51	8·46
Other matter, not determined	·89	2·54
	100·00	100·00

From these it is seen that the lower part is really an argillaceous marl containing nearly as much siliceous matter as carbonate of lime. The upper part is more calcareous, but seems to contain a large amount of carbonate of magnesia; taking the sum of the carbonates (68·06) it is nearly as calcareous as the lower part of the red chalk of Lincolnshire, while the lower part of the Speeton deposit approaches more nearly the red shale which separates some of the red chalk beds in Lincolnshire.

Analyses of Malmstones and Firestones.

Malmstone has been described in this volume as occurring in the counties of Surrey, Hants, Sussex, N. Dorset, Wilts, Berks, and Oxford. Some account of its nature and chemical composition has been given on page 54, but the following analyses will furnish the reader with more particular information on this subject. It is a fine-grained siliceous rock, the silica of which is largely in soluble colloid form.

Firestone is a similar rock differing only in having less colloid silica and a considerable amount of carbonate of lime, making it a harder and heavier rock.

Chert has also been described on p. 64, and an analysis by Mr. Meanwell of a sample from Godstone is given below. The cherts from the Chert Beds of Wiltshire, Dorset, and the Isle of Wight have probably a similar composition, for the microscope shows that they consist mainly of insoluble chalcedonic silica enclosing variable amounts of glauconite grains, shell fragments, &c.

Associated with cherts there are often lumps of white porous siliceous stone. Desiring to know whether these contained any colloid silica or were wholly composed of the chalcedonic form of that mineral, we sent two samples obtained from the Vale of Wardour to our friend Prof. J. B. Harrison of Georgetown, British Guiana. He submitted them to the careful and elaborate method of determining the several ingredients which has been specially devised by him for such siliceous rocks, and the results are given below.

[1] See Quart. Journ. Geol. Soc., xliv., p. 358.

The following are analyses by Messrs. Paine and Way,[1] (1) of the soft malmstone which overlies the Gault near Farnham, that is to say the lowest part of the malmstone series; (2) of a calcareous firestone:—

——	1.	2.
Combined water	4·15	1·60
Matter soluble in dilute acids:		
Silicic Acid	46·28	indet.
Carbonic Acid	—	35·47
Phosphoric Acid	trace	·15
Lime	·26	44·90
Magnesia	·07	·28
Potash	·79	·18
Soda	·43	·30
Oxides of iron	6·12	60
Alumina	3·15	1·46
Matter insoluble in dilute acids:		
Lime	2·91	·41
Magnesia	trace	·10
Potash	1·51	·07
Soda	·60	·43
Alumina with a little oxide of iron	14·20	·92
Silicic Acid and Sand	19·53	13·09
	100·00	99·96

The first material appears to consist entirely of colloid silica and argillaceous matter, with possibly some fine sand, but we doubt if the soluble silicic acid is all present as free colloid silica. The second is a sandy limestone containing nearly 80 per cent. of carbonate of lime, 9 or 10 per cent. of sand, and a little argillaceous matter. This was probably a very calcareous sample, for in the series given by them the most calcareous stone contained 74·96 of calcium carbonate with 8·20 per cent. of soluble silica.

The following are analyses of two malmstones by Prof. J. B. Harrison, made from samples supplied by ourselves, No. 1 being a typical Hampshire malmstone from a quarry south of Binstead, and No. 2 being an argillaceous malmstone from Sutton Mandeville in the Vale of Wardour, Wilts.

	——	1.	2.
	Organic matter and combined water	3·40	8·55
	Calcium carbonate	15·65	—
	Calcium sulphate	·03	—
	Colloid silica	34·97	11·40
	Quartz and mica	4·96	31·84
Argillaceous matter	Combined silica (by difference)	23·89	34·19
Argillaceous matter	Ferrous oxide	·18	—
Argillaceous matter	Ferric oxide	3·52	5·40 (Ferric oxide and Alumina)
Argillaceous matter	Alumina	10·38	
Argillaceous matter	Lime	·43	·71
Argillaceous matter	Magnesia	1·12	8·18
Argillaceous matter	Alkalis	1·47	indet.
		100·00	100·27

[1] Journ. Roy. Agric. Soc., vol. xii., p. 544

It will be seen that the first has a large proportion of colloid silica (35 per cent.), with over 15 per cent. of calcium carbonate, and not more than 46 per cent. of quartz, mica, and other siliceous ingredients. The other is very earthy, containing 80 per cent. of quartz and clay with only 11 per cent. of colloid silica and no carbonate of lime; there is also an appreciable amount of organic matter, for Prof. Harrison noted that the loss on ignition amounted to 3·80.

Messrs. Payne and Way state that the topmost bed of the Upper Greensand near Farnham is a rubbly mass of broken up rock 10 to 20 feet thick, which is impregnated with a notable quantity of phosphatic matter. In this many nodules of a pure white soft substance are interspersed, and an analysis of this substance gave the following result[1] :—

Insoluble siliceous matter	16·82
Soluble silica	12·92
Organic matter	2·29
Phosphoric acid	·78
Carbonic acid	22·54
Lime	34·68
Magnesia	1·01
Oxide of iron and alumina	6·29
Alkalis not determined.	
	97·33

If all the carbonic acid is combined with lime to form carbonate of lime, there is 51·22 per cent. of this material in the rock, leaving an excess of 6 per cent. of lime, of which ·92 is probably combined with the phosphoric acid and the remainder (5·08) is in the form of a silicate.

Mr. C. W. Meanwell has given the following analysis of Chert from the stone pits at Godstone, "a highly siliceous hard rock containing between 7 and 8 per cent. of carbonate of lime."[2] Dried at 100° C. "Average of two or three closely agreeing experiments" :—

Silica (insoluble)	87·10
Silica (soluble)	·21
Oxide of iron Fe_2O_3	1·59
Oxide of aluminium Al_2O_3	1·78
Lime, CaO	4·39
Magnesia, MgO	·28
Carbonic acid, CO_2	3·45
Alkalies (soda), Na_2O	·45
	99·25

As the amount of Carbonic Acid is exactly proportional to the amount of lime required to form carbonate of lime, we may assume that the amount of such carbonate present in the chert was 7·84 per cent. The oxides of iron, aluminium, magnesium, and sodium are probably present as components of the mineral glauconite, of which there may be between 7 and 8 per cent. The remainder of the stone, *i.e.*, about 85 per cent. will consist of pure silica, but how much of this is soluble in alkaline solutions was not determined.

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1 Journ. Roy. Agric. Soc., vol. ix. p. 74.

2 Handbook of the London Geological Field Class, by Prof. H. G. Seeley (1891), p. 79.

The following are analyses by Prof. J. B. Harrison of white porous siliceous concretions from the Chert beds of Wiltshire, No. 1 being from the railway-cutting near Baverstock, and No. 2 being from the road cutting north of Teffont.

——	1.	2.
Moisture	·10	·30
Loss on ignition - -	1·20	1·60
Colloid silica	2·10	4·30
Quartz	78·12	82·40
Clay - -	11·68	8·34
Iron peroxide and alumina -	1·20	2·40
Calcium oxide - -	·70	·71
Magnesium oxide -	·25	·29
Calcium carbonate	4·09	—
Calcium sulphate	·51	—
	99·95	100·34

It will be seen that in one of these specimens there is no carbonate of lime at all, and in the other one only 4 per cent. The amounts of colloid silica are also very small, and over three parts of the concretion consist of silica, entered under the head of quartz, which, in this case, means chalcedony. Microscopic analysis confirms this result.

CHAPTER XXIV.

MICROSCOPICAL STRUCTURE AND MINERAL INGREDIENTS OF GAULT AND RED CHALK.

By William Hill.

Examination of Gault clays and marls by means of the microscope shows that they consist partly of material in a very fine state of division, partly of fine detritus consisting of determinable minerals, such as quartz, mica and glauconite, together with the tests of minute organisms and the broken débris of such tests.

The colour is grey, darkest where the quantity of inorganic matter is large, lighter in samples which presumably contain more calcareous and organic material.

When thin sections of Gault are viewed by transmitted light, its appearance is that of a fine mud; its uniformity is hardly broken by the few larger fragments of shell and of rock débris which occur. Opaque masses and smaller opaque particles, probably compounds of iron, are abundant and give a dirty appearance to the whole; but the organic constituents, such as Foraminifera, Ostracoda and shell fragments, are more or less obscured by the fine material of the matrix. Where, however, grains of glauconite occur they stand out in strong relief.

When a thin section is viewed with polarised light and the Nicolls are crossed, a large part of the fine material is seen to be structureless, and to give no reaction with the light, so that the quartz-grains, the shell fragments, and other particles which give a strong reaction, seem to float in a translucent medium.

The examination of Gault by means of thin sections yields but little information as to the proportion of the different constituents of the clay, nor does it reveal any special structural characters by means of which any particular parts of the Gault can be readily recognised under the microscope.

In order therefore to obtain more definite information respecting the composition of Gault clays and what differences exist in samples from different horizons and different localities, it is necessary to break up a number of bulk samples, to wash and sieve them, and then to examine the different residues.

The process adopted will be described more minutely in the sequel; meantime for the purposes of general description, the Gault may be regarded as consisting of matter in three different forms or states of division:—

1. Coarse particles, easily recognisable under a $\frac{2}{3}$ lens.
2. Minute particles, only determinable under higher powers.
3. Very fine and apparently structureless material.

These are stated in order of coarseness but not in order of proportional importance in the bulk, for in ordinary Gault clays the quantity of coarse particles rarely amounts to more than 2 per cent.[1] The relative amounts of Nos. 2 and 3 vary considerably, but at Folkestone the structureless matter predominates in the Lower Gault, while in the Upper Gault the matrix consists more largely of minute but determinable particles. We now give some description of the several constituents in the order above-mentioned.

General Description of Ingredients.

1. Coarse Particles.

Derived Minerals.—In the identification of the mineral fragments that occurred in our coarse residues we have had the assistance of Mr. J. J. H. Teall. Mr. Teall remarks, "the very small amount of material available is not sufficient for an exhaustive study of the distribution of the heavy minerals, * * * probably others would be found if a larger amount of material were examined. Absence of reference to minerals in any given case must not be taken as evidence that they are absent from the deposit."

Of these derived minerals quartz is the most abundant. It occurs in every specimen examined in angular or sub-angular grains, the edges of which are usually worn; sometimes the grains are well rounded. As a whole those from different localities show no well marked differences, but they are occasionally stained brownish by an iron oxide. In size they range from 1 m.m. in the Gault from the base of Bindon Cliff, Devon, to the minutest particles.

Fragments of felspar, though not numerous, occur in the Gault from most localities, but were not recognised in that from Roydon in Norfolk. In size they compare with the average quartz grain and may be distinguished by their dull milky white appearance. Microcline was abundant in the Gault above the "Middle Greensand Bed" of Folkestone, and orthoclase in that of the Gubblecote boring (197 ft.). Small mica flakes were visible in nearly all specimens except those from Norfolk, and were most numerous in those from the west of England. Muscovite was abundant in those from the Bindon Cliffs.

Mr. Teall remarks that "selenite is certainly present in the specimen from the base of the Upper Gault of Folkestone." Of the heavy minerals zircon and rutile are the most common and probably occur in all Gaults, but only one prism of tourmaline (blue) was noted by Mr. Teall in any of the residues except those from Bindon Cliff, Devon, where this mineral was common. Magnetite (scarce), ilmenite (abundant),

[1] To this statement there are certain exceptions; the beds at its junction with the Lower Greensand often contain a large quantity of coarse particles; the highest marls at Folkestone and elsewhere contain 5 or 6 per cent. of such grains, and they are also noticeable in the layers of phosphatic nodules which occur at many horizons.

garnet, and cyanite all occurred in the coarse residues from this locality.

Secondary Minerals.—The most abundant secondary mineral found in the Gault is glauconite. It occurs as rounded grains not often exceeding ·5 m.m. in diameter. Generally dull exteriorly, its colour varies from dark green or nearly black, with clear glassy fracture, to a pale dull greyish green. Though much of this mineral is probably formed in the cells of Foraminifera such perfect casts as one often sees in the Lower Chalk are not commonly met with, and little trace of where they originated can be seen in the irregularly shaped, rounded, and sometimes mamillated grains. Glauconite rods, probably residuary spicular canals, are sometimes seen. Glauconite is not confined to any special horizon, but occurs in varying quantities in every specimen of Gault, sometimes, as in the "Middle Greensand" of Folkestone, making nearly 40 per cent. of the material.

Marcasite, (disulphide of iron) occurs in irregular masses, in short cylindrical lengths, or in minute spherules. In its formation it seems to form a cement; many pieces of Gault appear to be held together by the segregation of this material, and such masses of clay are studded with minute brassy metallic grains. Mr. Teall prefers to call the small nodules which occur in nearly all the residues marcasite, because it is like in form and appearance to those occurring in the Chalk. Of their formation he says: "The formation of iron sulphide (FeS) in the blue muds of modern seas has been shown by Murray and Irvine[1] to be due to the deoxidation of the sulphates of sea-water by decomposing organic matter and the union of the sulphur with the iron present in the deposits." In these clays, which may be compared with blue muds, a further change has taken place. The excess of sulphur left by the reaction described by the authors above-referred to has united with the FeS to form FeS_2

Marcasite frequently infills the chambers of arenaceous foraminifera, especially in the lower and middle part of the Gault.

Besides Marcasite there also occur reddish or yellowish brown ferruginous masses, sometimes roughly angular, or in cylindrical lengths, or in rounded nodules, more rarely as the cast of some organism.

Minute Organisms.—Foraminifera. Of the minute organisms revealed by the microscope the Foraminifera are the most numerous and of chief interest. They contribute but little, not one per cent., to the bulk of the material; but the ease with which they can be separated from the matrix and the number and variety of their forms should attract workers to a wide field of research.

The tests of Vitreous and Porcellanous Foraminifera found in the Gault seem to have altered but little from their original condition, and optically there seems little difference between tests from the Gault and those from recent deep sea soundings where

[1] Trans. Roy. Soc. Edin., vol. xxxvii., 1893.

the mud contains a considerable amount of terrigenous material, such as in Porcupine soundings 1000 fathoms. (? Bay of Biscay.)

The tests are frequently hollow, but the chambers are usually filled either with the finer material of the Gault or with crystalline calcite or marcasite, sometimes with glauconite, and rarely a cast may be seen in brown oxide of iron.

Tests of Arenaceous Foraminifera are comparatively small and puny in the lower beds of the Folkestone Gault, but become more robust at higher horizons, and the sandy particles of which the tests are built become at the same time much coarser.

With the exception of the excellent series of papers by Mr. Chapman,[1] no attempt has been made at a systematic record of the occurrence and distribution of the Foraminifera of the Gault. In the papers referred to Mr. Chapman has recorded the Foraminifera of the Folkestone Gault bed by bed, and has figured and described some 265 species and varieties. According to him the commonest forms of the Gault in this locality are *Globigerina cretacea*, *Anomalina ammonoides*, *Bolivina textilarioides* and *Haplophragmium nonioninoides*; but there are certain species which are especially abundant in the Upper Gault, these are *Textularia minuta*, *Verneuilina pygmæa*, *Gaudryina pupoides*, *Bulimina Presli*, *Nodosaria Römeri*, *Rotalia Soldanii* and *Miliolina venusta*.

Ostracoda.—Next to Foraminifera Ostracods are the most numerous organisms. Again it is at Folkestone that they have been worked systematically by Messrs. F. Chapman and C. D. Sherborn, who have published the results of their labours in the Geological Magazine.[2]

Prior to this, as early as the year 1849, Professor T. Rupert Jones figured and described the Entomostraca of the Cretaceous Formations, and he subsequently published a supplementary list.[3]

Ostracods occur in great numbers at many horizons in the Gault. Messrs. Chapman and Sherborn remark, "The extreme profusion of certain forms in particular beds is remarkable, and this segregation of species is often referable to the lithological differences met with in the various strata." They say further, "The slight connecting links of the Gault with the Jurassic Ostracoda on the one hand, with those of the Tertiary age on the other, have an additional palæontological interest." Messrs. Chapman and Sherborn enumerate 66 species and varieties as occurring in the Gault of Folkestone, the most abundant being *Cythere harrisiana*, which seems to occur in nearly every bed, but is most abundant between Bed 3 and the lower part of Bed 11.

Cythereis quadrilatera, very common in Bed 10 and the lower part of 11.

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1 "The Foraminifera of the Gault of Folkestone." Journal Roy. Microscopical Soc., 1892–1896.

2 Geol. Mag., August, Dec. 3, vol. x., p. 345, 1893.

3 Palæontographical Society, vol. iii., 1849, and vol. xlii., 1889.

Cythereis ornamentissima, with its varieties occurs at about the same horizon, while the var. *nuda* is found somewhat higher.

Cytheridea perforata is fairly abundant in all beds, with *Cytherella ovata* and *Münsteri.*

Shell-Fragments, &c.—Fragments of shell occur in all Gaults. Thin flaky pieces which may be recognised as belonging to Pecten, Nucula, &c., and prisms of Inoceramus shells are the most abundant. These in the Gault of Folkestone are almost always bored by parasitic plants which Dr. Scott[1] refers to the genera *Ostracolabe*, *Ostreobium*, and *Lythopythium.* Minute spines of Echinoderms also occur in many washings, those of the Folkestone Gault being referred to *Hemiaster* and *Pseudodiadema,* by Dr. Gregory.[2] Fragments of fish bone are not uncommon, while minute fish teeth are frequently seen.

Siliceous Organisms.—Sponge-spicules are rare in the Gault. Residuary canals of glauconite are met with in those parts of the Gault which contain this mineral in profusion. The spicule of an Hexactinellid sponge was met with in the Gault of Bucks, the spicular walls either replaced by or encrusted with Marcasite. We have been unable to recognise either Radiolaria or Diatoms.

2. *Finer Particles.*

Besides these coarser ingredients the finest part of the Gault is made up of minute calcareous atoms, some of which can yet be recognised as fragments of Foraminifera, and shells. Amongst these minute particles coccoliths take a prominent place, and are sometimes exceedingly abundant but appear to be all of the pseudo-coccolith type.[3] They are of the usual shape, ovate, with central disc and marginal ring The disc contains a nuclear spot, and is sometimes separated into two by a bar-like marking. More rarely it is ornamented by a cross similar to those of the chalk. In size they are small and rarely exceed ·015 m.m. in their longest diameter.

Rhabdoliths also occur in many samples, and are especially common in the pale grey Upper Gault of Kent.

3. *Finest Material.*

There yet remains a large amount of structureless material the real nature of which it is difficult to determine by optical means, and its amount is difficult to estimate. A portion is doubtless exceedingly fine rock fragments broken up by decomposition and attrition, and minute calcareous

[1] Foraminifera of the Gault of Folkestone, by F. Chapman. Trans. Roy. Mic. Society, 1891, p. 566.

[2] F. Chapman, Folkestone Gault, 1891.

[3] See G. Murray and V. H. Blackman, Phil. Trans., vol. cxc., p. 427.

particles which had their origin in the various organisms inhabiting the Gault sea. But when Gault has been treated with hydrochloric acid and the calcareous elements removed, and the sand as far as practicable removed by levigation, there remain shapeless aggregations of a structureless amorphous material, neutral to polarized light, colourless and translucent by transmitted light when the mass is not large, but when of some thickness a brown shade may be observed. Within these aggregations, when the Nicolls are crossed, are many points of light, an ill-defined crypto-crystalline appearance, as though minute particles of quartz had become entangled in the amorphous matter. This material is one of the chief ingredients of the Gault, and is probably a silicate of alumina derived from the decomposition of soda or potash felspars.

Mr. Teall has kindly shown us the section of a weathered felspar in which decomposition has begun to take place. A cloudy appearance is first seen in the clear crystals of the rock, which subsequently develops a crypto crystalline structure, as though the rock was breaking up into particles, each with its own optical axis. There was a strong resemblance in this part of the felspar to the minute particles entangled in the amorphous material of the Gault.

Description of Residues Examined.

To obtain some data for comparison between Gaults of different localities, the following examples were taken:—

1. A series of specimens from various horizons at Folkestone.

2. A number of specimens obtained from a boring made at Gubblecote, near Tring (Bucks).

3. Samples from the boring at Roydon, Norfolk (see p. 300).

4. Samples from the Gault exposed at the base of Bindon Cliffs, east of Seaton in Devonshire.

5. Besides these were three examples of Gault from the Medway Valley, two from Bedfordshire, and two from Wilts. In preparing these examples for examination the method employed by Dr. Hume was followed as far as practicable.[1]

No definite weight of material was however taken, the quantity being governed by the size of the specimen and amount of material at disposal. In each experiment the clay was dried for more than two hours at not less than 100° C., and then submitted to the action of a 20% solution of hydrochloric acid, for one and a-half hours, the lightest material gradually poured off leaving a residue of the coarser particles. To remove the calcium chloride, these residues were washed separately with hot water until there was no reaction, with a solution of nitrate of silver, then dried and weighed, and from these weighings the percentages of each was calculated. When it seemed necessary a further separation of the coarse residue was effected by passing it through three sieves of 30, 60, and 90

[1] See Chemical and Micro-mineralogical Researches on the Chalk (London, 1893), and The Cretaceous Strata of County Antrim, Quart. Journ. Geol. Soc., vol. liii. p. 540, 1897.

meshes to the inch, each division being weighed separately and the percentage by weight of each calculated. These divisions of the coarse residue will be referred to as A. B. C. and D. respectively, D. being that collected in the receiver below, after passing through the sieves. The fine clay which was separated from the coarser particles by the washing will be called the main residue.

This method of treating clays is not quite so satisfactory from a chemical point of view as when applied to chalks, for the Gault contains matter of varying degrees of solubility, and the amount removed depends on the length of time allowed for the acid to take effect. It was found in some specimens that when so far as could be ascertained the action of the acid had ceased, it began again briskly when hot water was added for washing purposes. Not only did this reaction occur among the coarser particles but in the fine residue also; it was specially evident in those specimens which contained phosphatic nodules.

In order to extract the coarser calcareous particles as well as those upon which acid had no effect, a fresh portion was washed (without acid) through the finest sieve C., and the percentage of the residuum estimated by weight. When specimens permitted 100 grammes were taken, in other cases a smaller quantity. It was found difficult to separate all the finest particles of sand from the coarse washings, small aggregations which had sufficient cohesion sometimes remained and were weighed with the coarse residues.

Small lumps of the clay frequently refused to break up after repeated washing and drying, but in the progress of these experiments it was found that a little washing soda added to the hot water effectually accomplished this in a few moments without injury to the Foraminifera.

All the coarse residues have been submitted to Mr. Teall, and Mr. Chapman has been kind enough to name all the Foraminifera we isolated in the washings.

Folkestone Gault.

The zones of the Gault of Folkestone have been studied by Mr. Chapman,[1] who not only examined the clay for its foraminiferal contents, but also worked out the percentage of the coarser particles of the various zones which he separated by levigation. He does not however in this paper give us the amount of soluble material. In order to compare with other examples seven specimens were taken from the Gault exposed in the cliffs at Copt Point. The results of their examination were as follows:—

No. 1, five feet from the base. Main residue 86·33 per cent. This consisted chiefly of the amorphous material of the clay, together with minute mineral particles, grains of glauconite, which were rather abundant, and a few minute foraminifera. Only ·47 per cent. of coarse particles was separated from the main residue and 13·20 per cent. of the material was dissolved by the acid.

The residue all passed through sieve A., and only 10 per cent. of it was retained by B. and C. In this the larger quartz grains were angular or subangular, with edges slightly worn. Their average longest diam. ·2 m.m., maximum ·38 m.m. A few small nodules of Marcasite, grains and rods of glauconite not numerous. A few masses of the clay not broken up by the acid were included as well as a few of the larger foraminifera.

The remainder, D., forms 90 per cent. It consists chiefly of fine quartz grains, amongst which a few fragments of an alkali felspar can be recognised, and much glauconite. Small nodules of Marcasite were common. Average size of the quartz grains ·08 m.m. Many small arenaceous foraminifera occurred, their cells frequently infilled with Marcasite.

The following species were noted—*Haplophragmium nonioninoides*, *Gaudryina pupoides*, *Bolivina textularioides*, *Anomalina ammonoides* and *Anomalina rudis*.

No. 2, fifteen feet from the base of the Gault. Main residue 85·70 per cent., coarse residue ·52 per cent., soluble in acid 13·78 per cent.

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[1] *See* papers in Journ. Roy. Mic. Soc., from 1891 to 1898.

The main residue was as usual the fine amorphous material of the clay; entangled in it are minute mineral particles which it appears impossible to separate.

It will be unnecessary to refer in detail to the main residues except to call attention to an especial peculiarity: they all resemble each other, their differences being reflected by the coarse residues, the finest particles of which come away with the amorphous matter of the clay.

The coarse residue is distinguished from the last by the abundance of minute nodules of Marcasite which form nearly the whole of the coarser material and the comparative absence of quartz and glauconite.

The Marcasite occurs in cylindrical, rounded, and angular masses Mr. Teall says of these, "The nodules, though only microscopic, are often precisely similar in form and general appearance to those occurring in the Chalk, and on this account are referred to Marcasite rather than the ordinary cubical pyrites." In some specimens the Marcasite has been more or less oxidized.

Mr. Chapman[1] says of the Gault at this horizon, "The fine washings yield 26·61 per cent. of iron in a state of ferrous oxide." In the finest siftings (D.) of the coarse residue minute reddish brown bodies occur; these are also referred to by Mr. Chapman as follows: "They appear to be casts of *Anomalina*, as a series can be made out graduating from the infilled shell of the foraminifera to the roughly spherical cast with its non-stained umbilical depression." They appear to be of carbonate of iron.

Mr. Teall says of this residue, "Selenite is certainly present." This mineral occurs in minute aggregations, which at first sight are not unlike the bodies above referred to. The few quartz grains averaged ·1 m.m. maximum ·18 m.m.

Arenaceous foraminifera not numerous and small; there occurred *Haplophragmium* (three species), *Gaudryina filiformis* and *Lagena apiculata*.

No. 3. Base of the Upper Gault. Main residue 59·19 per cent. Coarse residue ·23 per cent., soluble in acid 40·58 per cent.

More than half the coarse residue of this specimen (A. B. and C.) consisted of nodules of Marcasite, the external appearance of which is more silvery than those below.

The remainder D. consisted of fine quartz and glauconite grains, averaging about ·08 m.m. in their longest diameter, a few spheres of Marcasite and a very large number of the minute bodies already referred to.

Arenaceous foraminifera were more abundant and robust; the following species occurred—*Haplophragmium nonioninoides*, *Ammodiscus incertus*, *Trochammina concava*, *Gaudryina dispansa*, and *Gaudryina pupoides*.

No. 4. Base of the bed locally known as the Middle Greensand. Main residue 38·20 per cent., coarse residue 40·14 per cent., soluble in acid 21·66 per cent.

As might be expected from the character of the coarse residue, the main residue contains an exceptional number of minute grains of glauconite.

The coarse residue is nearly all glauconite, and when separated in three divisions, by sifting, shows the comparative size of the grains, which appear well rolled. That retained by the A. and B. sieves is 2·3 per cent., chiefly glauconite grains, and pieces of a dull greenish material easily crushed but somewhat tough. Average size of glauconite grains, ·35 m.m., two or three large quartz grains, maximum ·43 m.m., and three large arenaceous foraminifera (*Bulimina Presli*).

More than half the residue consists of medium-sized grains and is retained in sieve C., 52·9 per cent. The tests of arenaceous foraminifera are estimated to form 3 per cent. of this division, the remainder nearly pure glauconite in grains averaging ·15 to ·18 m.m.

D. The remaining 44·8 per cent. similar to C., but finer, containing a large proportion of quartz averaging ·1 m.m. Spheres of Marcasite occurred.

Mr. Chapman, remarking on the glauconite of this bed, says,[2] "A noteworthy point about this deposit is that the glauconite casts have been formed at a less depth than that at which the associated

[1] Journ. Roy. Mic. Soc., 1891, p. 568.
[2] Natural Science, Nov. 1898, p. 310.

foraminifera lived; for the foraminiferal tests, mingled with the glauconitic casts . . . undoubtedly belong to a later period than the originals of the casts themselves."

No. 5. Bluish-grey Gault about three feet above the Greensand Bed. Main residue 66·18 per cent., coarse residue ·73 per cent., soluble in acid 33·09 per cent. With the exception of a few large mineral grains and nodules of Marcasite (numbering in all about a dozen) and an equal number of the larger arenaceous foraminifera (*Bulimina Presli* and its variety *sabulosa*) the whole of this coarse residue passed through all sieves. It consists of very fine sand and minute grains of glauconite, the latter estimated at 10 per cent. of the residue. Mr. Teall notes that "grains of quartz and felspar (microcline) are abundant, with some zircons, and one small prism of blue tourmaline was observed besides a few small spheres of Marcasite." The sand grains are very even in size and average about ·05 m.m. to ·08 m.m. in their longest diameter.

No. 6. Pale grey Gault, four feet above the last. Main residue 69·04, coarse residue 1·13 per cent., soluble in acid 29·83 per cent.

The clayey matter of the main residue contains more mineral particles than the last examples, fragments which appear to be foraminiferal debris (arenaceous), and minute grains of glauconite being also more numerous.

No division was necessary in the coarse residue; it consisted entirely of fine sand, chiefly quartz, with arenaceous foraminifera and glauconitic grains, the average size of the quartz grains being about the same as in the last example.

Arenaceous foraminifera were abundant in point of numbers, but *Bulimina Presli* and its variety *sabulosa* were the only species noted.

No. 7. Pale grey Gault, five feet below the Chloritic Marl. This specimen, though a clay, has a distinctly different feeling in the hand when compared with those below; it reminds one of the silty beds in the lower part of the Upper Greensand. Main residue 66·82 per cent., coarse residue 5·74 per cent., soluble in acid 27·44 per cent. The coarse residue was similar to the last. Glauconitic grains, which in this specimen included casts of spicular canals were, however, more abundant, their estimated proportion in this division being 15 per cent. Mr. Teall recognises amongst the sand grains fragments of an alkali felspar, while the heavy minerals, zircon and rutile, are more frequent than in any of the other specimens.

The average size of the sand grains is rather larger, viz., ·1 m.m. Arenaceous foraminifera abundant; the following were noted, *Haplophragmium nonioninoides*, *Tritaxia tricarinata* and *pyramidata*, *Bulimina Orbignyi*, *B. obtusa*, and *B. Presli* and its variety *sabulosa*.

A further examination of these specimens was made by washing one hundred grammes of each through the finest sieve (C.) and ascertaining by weight the proportion of the coarse residuum. A similar estimate has been made by Mr. F. Chapman,[1] who separated the coarse particles by levigation. Our own observations agree with his, and show how small is the proportion of recognisable particles, organic or inorganic, in the mass of the Folkestone Gault.

The first two specimens (1 and 2) yielded a residuum just under one per cent. This consisted, partly of the minerals already described, but also contained grains of quartz, glauconite, nodules of marcasite and shell fragments (chiefly of Pecten and Nucula), minute spines of an Echinoderm, Foraminifera, and the valves of Ostracods; also a few scales and teeth of Fish. It is difficult to estimate the proportions of organic and inorganic particles, but ·53 gramme gave a residue of ·17 gramme, or a loss of 66 per cent., chiefly due in all probability to the calcite contained in the organic constituents.

Specimen 3 yielded a larger residuum, 1¼ per cent., the major part of which consisted of shell fragments, chiefly thin and flaky like the preceding, but containing prisms and fragments of Inoceramus which were absent in 1 and 2. Many of these shelly fragments seemed to have become

[1] Journ. Roy. Mic. Soc., 1891, p. 566.

thickened by the redeposition of calcite. A few large glauconitic grains occurred measuring ·35 m.m., none such occurring in the acid residue. There was also a well-marked cast of a small bivalve and a round nodule, both of brown ferruginous material (?oxidized marcasite). This specimen is a rather calcareous gault, and examination of the finest material showed that pseudo-coccoliths were much more abundant than in the clay below, and must form an appreciable quantity in the fine matrix. There were also a large number of distinct separate crystals of calcite, rather minute, but apparently no part of any recognisable organism.

Specimen 4. The "Middle Greensand" gave a residuum of 27 per cent., and 5 per cent. of this consisted of minute phosphatic nodules, or fragments of such, while many smaller pieces could be noted in that part of the material which had passed through the sieve. The remainder seemed pure glauconitic grains and foraminifera. Shell fragments in this were comparatively rare; a few flaky pieces and some prisms of Inoceramus shell occurred, and the small spine of an Echinoderm.

In the fine washings which had passed through the sieve small glauconitic grains were very abundant, with minute foraminifera and sand grains.

In specimen No. 7 the material was so fine that, with the exception of the larger foraminifera, nearly all passed through the sieve. The residuum, less than 1 per cent., consisted of foraminifera and brown particles, probably oxidised marcasite, and one or two silvery nodules of that mineral.

Aylesford and Burham.

Three other specimens of the Kentish Gault were examined; one from the pale-grey gault at the top of the pit at Aylesford, one from a few feet below this in bluish-grey clay, and a third from the pale olive grey gault in the upper part of the pit at Burham. The residues are given on page 350.

The two pale-grey clays from Burham and Aylesford are practically alike. In the coarse residues from both there was comparatively a very little quartz sand, and they consisted almost entirely of brown ferruginous nodules which may be oxidised marcasite, and a few nodules of this mineral unaltered. A very few glauconitic grains. Arenaceous foraminifera constitute at least 5 per cent. of these residues; they are fine bold specimens, among which *Bulimina Presli* and a *Tritaxia* are conspicuous.

Both are calcareous gaults, and when fine washings (without acid) are examined, minute foraminifera, *Globigerinæ*, *Textularians*, &c., are seen to be very numerous. Pseudo-coccoliths and Rhabdoliths are very abundant. Mineral grains of all kinds are scarce.

The third specimen from just below the pale-grey clay at Aylesford is like the two preceding in the absence of quartz and glauconite, but while foraminifera seem to be almost as common, analyses show that the proportion of calcite is not so large.

When viewed in thin sections under the microscope all three of these specimens seem to be the finest and most evenly constituted clay of all those examined.

Gault in Boring at Gubblecote, Bucks.

This boring, which pierced nearly the whole of the Gault in this locality, was made at the instance of Mr. Jukes-Browne to prove the thickness of the clay. Particulars of it have been given on page 282.

Six specimens were taken for examination

No. 1 from 222 ft. Main residue 36·89 per cent. Coarse residue 36·20 per cent. Soluble in acid 26·91 per cent.

The coarse residue was a quartzose sand, evidently derived from the top of the Lower Greensand, and churned up by the boring tool.

No. 2, 210 ft. Main residue 78·98 per cent. Coarse residue 1·53 per cent. Soluble in acid 19·49 per cent.

The main residue was chiefly fine amorphous material, rather more dirty than that of Folkestone, containing a greater number of black specks and particles; there were but few fine mineral particles and scarcely any glauconite. The coarse residue when sifted was divided into three parts; the first, B.29 per cent., consisted of a few masses of clay not broken up by the acid and a large number of ovoid forms alike at both ends made up of the finest material of the clay, easily broken on pressure, but disclosing no structure. The largest were ·35 m.m. long by ·15 m.m. width. Subsequently repeated drying and washing with hot water and soda failed to break them up.

Bodies of a very similar nature were observed in certain muds obtained by the Challenger Expedition, of which the following description is given[1]:—

"In examining samples of Blue muds, and especially those near the mouths of rivers, many oval-shaped bodies about ·5 m.m. in length were observed. These were described by some observers as Foraminifera. Mr. Murray, after numerous observations, came to the conclusion that they were mostly the excreta of Echinoderms, principally Holothurians. When these pellets are voided by the animal they are covered by a slimy substance; many of them may indeed be united in a chain. In some deposits this dung is exceeding abundant, but as a rule it is impossible to recognise these oval bodies in any of the organic oozes . . .They appear to fall asunder when the deposit is granular like a Globigerine ooze." . . .

There were about a dozen large mineral grains mostly glassy quartz; amongst them were some fragments of an alkali felspar. The maximum size of these grains was ·5 m.m. There were also a few grains of glauconite ·35 m.m. in their longest diameter. Foraminifera were not common; those occurring were large bold specimens of *Haplophragmium nonioninoides*.

C. 44 per cent., much the same character as the preceding, but smaller particles.

D. 27 per cent. Mineral grains averaging about ·1 m.m. and a few of glauconite. The minute reddish-brown bodies noticed in the Folkestone Gault 15 feet above the base were extremely numerous and were estimated to form quite two-thirds of this part of the coarse residue.

No. 3. 197 feet. Main residue 74·92 per cent. Coarse residue 7·33 per cent. Soluble in acid 17·75 per cent.

Minute mineral and glauconitic grains occur in the main residue, the latter in some abundance.

The coarse residue was divided into three parts by sifting.

B. 11 per cent. Nearly all glauconite with a few quartz grains averaging ·3 m.m. and a few arenaceous foraminifera, *Tritaxia tricarinata* and *Bulimina Presli*.

C. 17 per cent. Similar to the last. The mineral grains about ·22 m.m.

D. 72 per cent. Still smaller grains of glauconite, but with a larger proportion of detrital minerals; average size of the mineral grains ·12 m.m. Among the mineral grains Mr. Teall recognises orthoclase.

No. 4. 187 feet. Main residue 62·21 per cent. Coarse residue ·37 pe cent. Soluble in acid 37·42 per cent.

The main residue is fine amorphous matter with minute mineral particles and glauconite.

The coarse residue was a fine pure white quartz sand with little glauconite, the whole so fine that it passed through the sieves with the exception of a few arenaceous foraminifera; average size of grains, ·1 m.m.

No. 5. 151 ft. Main residue 52·16 per cent. Coarse residue 2·95 per cent. Soluble in acid 44·89 per cent.

[1] Oceanic Deposits. Report of the Challenger Expedition, page 254.

The coarse residue of this specimen was peculiar. It divided into four portions when sifted.

A. 17 per cent. Consisted of one cylindrical mass of marcasite, and the remainder was in irregular lumps of reddish-brown colour, which seemed partly clay and partly marcasite, and seemed to be cemented together in the formation of this mineral. A single grain of quartz measuring 1 m.m. occurred.

B. 10 per cent. Similar aggregrations of clay and marcasite, though smaller. Amongst these masses was the mesh of an Hexactinellid sponge with marcasite either encrusting or replacing the siliceous walls. There are many grains of clear glassy quartz averaging about ·25 m.m. in size, and some glauconite.

C. 10 per cent. Similar to the last but the grains smaller, ·19 m.m.

D. The remainder consisted of minute masses of marcasite and clay with a larger proportion of quartz grains which averaged about ·11 m.m.

Foraminifera occurring were *Haplophragmium nonioninoides*, *Bulimina Presli*, *Bulimina pupoides*, and *Ammodiscus incertus*.

No. 6. 1 to 17 feet. Main residue 72·72 per cent. Coarse residue ·79 per cent. Soluble in acid 26·49 per cent.

The main residue appears of the usual character.

The coarse residue, with the exception of about a dozen quartz grains, all passed through the sieves. These grains were of somewhat exceptional size, their average being about ·37 m.m., the maximum being ·42 m.m.

The remainder, which may all be included under D., consisted of fine sand ·11 m.m. with some glauconite, estimated at about 7 per cent.

A washing (without acid) through the finest sieve was made of specimens 3, 4, and 5.

No. 3. This is clearly a phosphate bed, and may be compared with the "Middle Greensand Bed" of Folkestone, though glauconite is not so abundant. The residuum was 11 per cent., chiefly glauconite. Such shell fragments as occurred were prisms of Inoceramus, and pieces of the shell. Microzoa were not common, but the specimens seemed finer of their kind than at an equivalent horizon at Folkestone. Pieces of phosphates were abundant.

In No. 4 the residuum after washing was 2 per cent. Shell fragments were abundant, Inoceramus-prisms and pieces of the shell forming the greater part of them. Microzoa were fairly common, the mineral grains similar to those of the acid residues.

No. 5. The residuum of this specimen was 2¼ per cent.; from the number of nodules and fragments of clay with marcasite it resembled that of the acid. Shell fragments were abundant, and as before were chiefly prisms and pieces of Inoceramus. Many foraminifera and a few Ostracod valves were also present. Both these specimens are rather calcareous Gaults, and in both coccoliths were conspicuously abundant in the fine washings.

Bedfordshire Gault.

Two specimens of the Gault of Bedfordshire were examined, one from about 6 feet below the Cambridge Greensand at Arlsey (Messrs. Beart's Works, Three Counties Station), and a second about 70 feet below this at Messrs. Eastwood's, close to Arlsey Station.

1. In that six feet below the Cambridge Greensand the Main residue was 65·72 per cent. Coarse residue 17 per cent., soluble in acid 34·11 per cent.

The main residue was fine amorphous material with minute mineral particles.

The coarse residue resembled that at Burham and Aylesford, chiefly yellowish-brown or red-brown cylindrical or subangular fragments of a

ferruginous material. There was very little quartz or glauconite; grains of the former average only ·06 m.m. Arenaceous foraminifera were common and the specimens large.

A washing without acid gave a residuum of 1·2 per cent. largely ferruginous fragments, but with many Ostracods, Foraminifera and few shell fragments. Among the Ostracods Mr. Chapman found *Cythere subtuberculata*, hitherto only recorded from the Cambridge Greensand.[1]

2. 70 feet below the Cambridge Greensand, Arlesey Station. Main residue 63·34 per cent. Coarse residue, ·20 per cent. Soluble in acid 36·46 per cent.

The coarse residue contained a few nodules of marcasite, a few grains of quartz averaging ·3 m.m. The remainder is finer quartz (·1 m.m.) and a little glauconite; fragments of the pyritous cast of some organism contributed about one-third of the weight of this residue.

A washing without acid gave a residuum of 1·6 per cent. consisting of shell fragments, foraminifera (abundant), valves of Ostracods, &c., besides a few somewhat large quartz grains and a little glauconite.

Gault, Bindon Cliff, Devon.

Three specimens of the Gault exposed at the base of Bindon Cliff, Devon, were examined.

No. 1. In that from the base of the Gault the fine residue was 73·69 per cent., coarse residue 19·59 per cent. Soluble in acid 6·72 per cent.

This, though a very sandy specimen, was a true clay, pressure by the thumb-nail leaving a shining streak. It contained pieces of shell visible to the naked eye.

In the fine residue the proportion of minute mineral grains was very large and the amorphous material when viewed by transmitted light was dirtier than usual, being full of minute black specks.

Only 3 per cent. of the coarse residue remained in the sieves A., B. and C. This consisted chiefly of quartz grains, but there were also fragments of an alkali felspar, muscovite, and ilmenite, cylindrical masses and nodules of marcasite and grains of glauconite. Average size of the quartz grains ·38 m.m.

D. 97 per cent. Chiefly fine quartz sand and with green grains. The latter were estimated to form 10 per cent. of this division; some of them were the usual dark-green crystalline glauconitic grains, but a large number, while corresponding in shape and size, were of a pale-green colour, dull and opaque. A few crystals of zircon were also recognised.

Arenaceous foraminifera were rare, but *Verneuilina variabilis*, *Tritaxia pyramidata*, and *Haplophragmium nanum* occurred. Washings of this specimen without acid were nearly the same as those of the acid residues; the finest portion, however, differed from all other Gaults in the complete absence of coccoliths.

No. 2. A very sandy clay. Main residue 51·76 per cent. Coarse residue 45·77 per cent. Soluble in acid 2·47 per cent.

The main residue contained very little amorphous material, nearly the whole of it being very minute mineral grains. The coarse residue may be separated into three parts.

A. and B. 7 per cent. Consisting of coarse quartz-grains, maximum ·45 m.m., average ·32 m.m., one or two nodules of marcasite, and glauconitic grains estimated at 3 per cent. of the whole.

C. 8 per cent. The mineral grains in this division are quartz and alkali felspar, their average size ·28 m.m. Glauconite grains of about the same average size form 20 per cent. of this division.

D. 85 per cent. Consisted of quartz and alkali felspar, average size ·12 m.m., while the glauconitic grains were estimated at 12 per cent.

The heavy minerals of this residue were roughly separated by running,

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[1] Ann. Mag. of Natural History Ser. 7, vol. ii., October 1898.

and were found to include zircon, magnetite (scarce), ilmenite (abundant), rutile, tourmaline, garnet and cyanite.

No. 3. A similar clay to the last specimen.

Main residue 56·71 per cent. Coarse residue 40·49 per cent. Soluble in acid 2·80 per cent.

The main residue was similar to the last.

The coarse residue may be separated in but two portions.

A., B. and C. 1 per cent. Consisted largely of subangular masses of a brown ferruginous material which seemed to be clay cemented by an iron oxide, a few large quartz grains, maximum 1 m.m., and the remainder either grains of glauconite or of the dull opaque material noted in No. 1.

D. 99 per cent. Chiefly quartz grains, average size ·12 m.m. Zircon, rutile and muscovite were also recognised. Glauconite and greenish opaque grains were estimated at 7 per cent.

Mr. Teall remarks on these specimens: "There is no doubt that the list of minerals in these residues might be considerably increased by separating the heavy minerals. Felspars are comparatively rare; the only one definitely recognised is an alkali felspar, but it is quite possible that some oligoclase may also be present."

Gault, Devizes.

Two specimens of Lower Gault from the Caen Hill brickyard west of Devizes were kindly forwarded to us by Mr. Heward Bell of Seend.

No. 1. Fine residue 86·69 per cent., coarse residue 10·63 per cent, soluble in acid 2·68 per cent.

The fine residue was similar to that of the specimens from Bindon Cliff, dirty, full of black specks and minute mineral particles. Very small grains of glauconite were also common. The coarse residue of this specimen consisted largely of glauconite grains. On sifting it was divided as follows:—

A. and B. 11 per cent. Consisting of almost pure glauconite-grains with very little quartz. Average size of grains ·33 m.m., maximum ·5 m.m.

C. 26 per cent. Chiefly glauconite, average size of grains ·24 m.m., with a few of quartz and some flakes of mica. Two or three arenaceous foraminifera.

D. 63 per cent. Fine mineral grains chiefly quartz but including an alkali felspar, some mica flakes and grains of glauconite, the latter estimated to form 30 per cent of this division. The mineral grains average ·1 m.m.

No. 2. Fine residue 83·42 per cent., coarse residue 13·19 per cent., soluble in acid 3·38 per cent.

The main residue is similar to the last.

The whole of the coarse residue passed through all sieves except a few quartz and glauconite grains and one or two tests of arenaceous foraminifera.

It consists of mineral grains, chiefly quartz, with a few of an alkali felspar, some mica flakes, and glauconitic grains; the last being estimated at 12 per cent of the whole. The mineral grains average ·11 m.m. A few nodules of marcasite occurred.

Arenaceous Foraminifera were fairly common, their tests robust and made up of coarse quartz and glauconite grains. All the species occur in the Gault of Folkestone, though their characters indicate conditions very different from those in which the Kentish Gault was deposited. Mr. Chapman remarks, "These forms would occur in deposits poor in calcareous material and under adverse conditions." The list of these specimens is given on p. 351. In the fine washings of these specimens (without acid) coccoliths were entirely absent.

Norfolk Gault.

The boring at Roydon was made in the year 1887 in order to ascertain the thickness of the Gault in this locality.

No. 1. Carstone from the bottom of the boring. Main residue 36·17 per cent., coarse residue 59·07 per cent. Soluble in acid 4·76 per cent The residues were practically all sand.

No. 2. 15 feet down. Main residue 49·75 per cent. Coarse residue ·23 per cent. Soluble in acid 50·02 per cent.

The main residue was almost entirely fine amorphous structureless matter, and there was a notable diminution of the fine mineral particles usually entangled with it. The coarse residue divided by sifting into three parts.

B. 30 per cent. Consisted of a few thin flaky pieces of the clay, not broken up in the acid, several ovoid bodies described on page 340 and fine clear glassy quartz, average size ·3 m.m. Three or four large grains, maximum ·5 m.m., are included in this division.

C. 30 per cent. Two small nodules of marcasite, small ferruginous nodules and a few pieces of clay. The remainder, chiefly quartz grains· average size ·18 m.m. Very little glauconite.

D. 40 per cent. Fine quartz-sand with rather more glauconite, average size of grains ·08 m.m. About one-third of this division consisted of the minute red-brown bodies described in the Folkestone Gault (see page 337).

No. 3. 13 feet down. Main residue 34·51 per cent. Coarse residue ·82 per cent. Soluble in acid 64·67 per cent.

The main residue contains more mineral particles than No. 2.

B. 18 per cent. Clear glassy quartz, average size of grains ·35 m.m., one grain ·43 m.m. Only a few grains of glauconite.

C. 49 per cent. The same, but finer. Arenaceous Foraminifera common *Bulimina Presli* is the most prominent form, the tests large and robust.

D. 33 per cent. The same, particles still finer.

No. 4. 11 feet down. Main residue 36·80 per cent. Coarse residue ·40 per cent. Soluble in acid 62·80 per cent. The main residue almost entirely very fine amorphous matter. The greater part of the coarse residue was unfortunately spilt, and there was no more material at hand. That saved contained a few large grains of quartz and a few foraminifera.

No. 5, 8 feet down. Main residue 29·89 per cent. Coarse residue ·89 per cent. Soluble in acid 69·22 per cent.

The coarse residue of this specimen again contains rather coarse quartz, and was separated into three parts on sifting.

B. 23 per cent. Chiefly quartz sand with a few fragments of unbroken Gault. There appeared to be two varieties of the larger quartz-grains, one worn, often well rounded, iron stained or cloudy, the other clear, bright, glassy and less worn, size ·3 m.m.

C. 17 per cent. Finer quartz, many small arenaceous foraminifera, more glauconite than in the preceding specimens, and some small nodules of Marcasite.

D. 60 per cent. Still finer quartz, hardly any glauconite, minute foraminifera. Average size of quartz grains ·1 m.m.

Parts of several of these specimens were washed through the fine sieve (without acid), but the quantities were too small to estimate the percentage of the residuum; but sufficient material was found in a specimen from the Grimstone railway cutting; it was from near the base of the Gault, and from the presence of the ovoid bodies before referred to, was probably at the same horizon as the specimen from 15 feet down the boring.

The residuum from 100 grammes of this was only ·93 per cent.

Besides mineral grains and ovoid bodies, which were numerous, the shell-fragments consisted wholly of Inoceramus-prisms, or pieces of the

shell; valves of Ostracods were not so common as in the Gault more to the S.W.; Foraminifera were abundant, and the specimens large and bold.

As may be expected from the large proportion of material soluble in acid, the fine washings consist largely of calcitic particles. These, probably derived from the organic constituents of the rock, seem undergoing a secondary crystallisation, the calcite dissolving and recrystallising either on definite organic particles or as separate granules. Thus the pseudo-coccoliths, which are abundant, are nearly all partially obscured by the redeposition of calcite, a phenomenon observed before in certain oceanic deposits from Barbados.[1]

Though little information can be obtained as a rule from thin sections of the Gault, that of N.W. Norfolk—Roydon and Grimstone, where the upper part of the Gault has become calcareous—thin sections of the upper portion exhibit a striking contrast to the Gaults of the Southern Counties. In the grey shade produced by the amorphous matrix are outlined the tests of Foraminifera and shell fragments, one of the most remarkable features being the incoming of calcareous "Spheres."[2] These minute bodies, formerly regarded as the primordial or disunited cells of Globigerinæ, are nearly always present in chalk and often form a large part of its mass; they occur rarely in the upper part of the Upper Greensand. It is only in this locality and in the Red Chalk that they appear at so low an horizon. Their incoming at Roydon is sudden and striking; not occurring at all near the base, they make their appearance in the lower hard bed. Above this the material is often densely packed with spheres, and other foraminifera are abundant.

Red Chalk.

Only one specimen of Red Chalk was analysed. This was kindly forwarded from Hunstanton by Mr. Lamplugh and was taken 2 feet above the base.

The result of the analysis was as follows:—Main residue 6·67 per cent., coarse residue 15·01. Soluble in acid 78·32 per cent. The main residue has a distinctly different aspect from that of the Gault, even from that so near at hand as Roydon. The whole of the amorphous matter is practically neutral to polarised light, and the ill-defined crypto-crystalline appearance which seems to arise from the minute mineral particles entangled within it is absent, nor does there seem the usual gradation in the size of the mineral grains from particles sufficiently large to be recognised as quartz to those so small that their identification is difficult. Nearly all are above ·05 m.m. The amorphous matter viewed by transmitted light shows a red stain, but there is no optical evidence which will explain this colouration.

The coarse residue reflects the characters of the fine residue. On sifting this was separated in four parts as follows. A. 20·29 per cent. B. 38·90. C. 31·80. D. 9·01. Thus the division D., which in every specimen of Gault contains the largest proportion of the coarser residue, is here the smallest.

Except in the size of the grains there was little difference in the first three divisions. Quartz grains are the most abundant, and then the highly polished brown-black grains of Lydian stone; a few milky-white grains, probably a felspar, were observed. Glauconitic grains were not common, but nodules of a porous ferruginous material occurred in each division. Glauconitic grains were most numerous in D., and were estimated to form 10 per cent of this division. Many of these grains appear to be partly decomposed and were brown in colour.

Foraminifera were fairly common and the specimens of fair size. *Bulimina Presli* seemed the most conspicuous.

The minute structure of the Red Chalk is, however, best displayed by means of thin sections. A long series of these was made by the writer

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[1] Geology of Barbados, Q. J. G. S., vol. xlviii., pages 178 and 179.

[2] Journal Roy. Mic. Soc., 1891. Burrows, Sherborn and Bailey on the Foraminifera of the Red Chalk.

some years since in the course of his work in the description of the lower beds of the Upper Cretaceous series in the counties of Norfolk, Lincolnshire, and Yorkshire.

Any slide of this series when viewed by transmitted light with an objective of two-thirds in focus shows that the Red Chalk is made up of fine amorphous matter now finely granular crystalline calcite, in which are outlined the forms of foraminifera and shell fragments, and in which is imbedded mineral grains. Except for these the aspect of the rock is that of a specimen of Lower or Middle Chalk, though it is not possible to compare it to any definite horizon. The most abundant organisms are "spheres" which in some instances form at least half the rock.

Foraminifera are common. Messrs. Davis and Sherborn,[1] who examined these sections, have published a list of those identified. Sponge mesh and single spicules are frequent, their siliceous walls now invariably replaced by calcite. In a section of the rock from Great Givendale, and also in one from Hunstanton, partially obliterated organisms occur, similar to those which can be identified as Radiolaria in the rocks of Barbados.[2]

The rock is, however, not uniformly chalk-like. The lowest part contains much inorganic matter (clay), which, stained a deep red, is opaque, and cannot be viewed in thin sections; there is, however, a rapid passage to conditions under which was formed a deposit very similar to the Chalk. Not only is there a considerable admixture of fine clay, but through Lincolnshire and in Yorkshire along the escarpment as far as Wharram[3] the rock contains an abundance of mineral fragments probably derived from the underlying beds. At Speeton there is a passage from the blue Speeton clay to the Red Chalk, and the included siliceous matter is entirely of an argillaceous nature.

The residues of the samples of Red Chalk from Lincolnshire, analysed by Dr. Pollard (see p. 325), were examined by Mr. Teall; slides were also prepared from the specimens, and on this material Mr. Teall reports as follows:—

"The two specimens from Langton sand-pit do not differ materially so far as the nature of their constituents is concerned. The residues consist of fine argillaceous material, minute angular chips of quartz and felspar (orthoclase and probably also oligoclase), grains of glauconite, and large waterworn grains or small pebbles of quartz and chert. Heavy minerals, such as generally occur in fine sedimentary material, were not specially searched for, but zircon, rutile, and tourmaline were observed. The clastic particles of quartz and felspar vary in size from extremely minute chips less than ·1 m.m., up to small pebbles more than 3 m.m. in diameter. A slice of the sample taken two feet above the base of the Red Chalk is seen under the microscope to consist of a calcareous matrix, deeply stained with ferric oxide, but consisting largely of foraminifera. In this matrix are scattered the mineral grains above mentioned.

"A section of a specimen from the bed two feet above the junction with the sandstone was prepared. It shows that the rock consists largely of a foraminiferal ooze, stained with finely divided ferric oxide. Grains of quartz and glauconite occur in the slice, thus proving the intimate intermixture of a calcareous organic ooze, with both fine and coarse sedimentary material. This association of deposits, which are characteristic of distinct and often widely separated zones of sedimentation, gives to the rock a peculiar and interesting lithological character.

"The residue of the specimen from Langton chalk-pit, two feet below the junction with the Chalk, consists of small particles of quartz, felspar (orthoclase), minute flakes of a micaceous mineral and fine argillaceous material. The grains rarely exceed ·1 m.m. in diameter. Coarser sandy material, such as that found in the other specimens, is absent."

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1 Journ. Roy. Mic. Soc., 1890, p. 564.
2 Q. J. G. S., vol. li. p. 600.
3 Q. J. G. S., vol. xliv. p. 355.

Remarks on the Residues Described.

These analyses which are tabulated on p. 350 show that the Gault, throughout the central part of the Gault area, is an extremely fine mud, possessing few marked peculiarities in regard to its chemical and microscopical properties by which one portion may readily be distinguished from another.

It will be observed, however, that the base and centre of the Upper Gault at Folkestone contain a greater proportion of soluble material than the beds below, or those near the summit of the Gault. This increase seems due to the greater abundance of the shelly fragments and foraminifera as well as to particles of calcite of uncertain derivation, while pseudo-coccoliths certainly add appreciably to the amount of soluble material by their increased numbers.

In Norfolk also the analyses of the specimens from the Roydon boring show a great augmentation in the proportion of soluble matter, and here again, shell fragments, foraminifera, and pseudo-coccoliths are numerous, though the amount of the recognisable remains of calcareous organisms seems hardly in proportion to the increase of soluble material. The amorphous matrix of the Gault here consists largely of calcitic particles, which seem to have undergone a kind of secondary crystallisation, and there is no trace of structure from which one may infer their original derivation.

In the central area of the Gault the quantity of the coarser particles separated by levigation from all the acid residues is very small except in special cases, rarely exceeding 1 per cent.; the coarsest particles being secondary and not detrital minerals. Of these secondary minerals small nodules of marcasite and porous ferruginous masses are conspicuous in almost all residues.

The number of grains of quartz or felspar larger than ·3 m.m. could usually be counted on the fingers, and the average size of the mineral grains of the coarse residues will not exceed ·1 m.m. in their longest diameter, though in some specimens they are coarser than in others. The increase of quartz sand and glauconite at the top of the Folkestone Gault seems to indicate the gradual approach of the conditions of the Chloritic Marl, but there is no indication of a similar approach in the pale-grey Gault taken just under the Chloritic Marl at Aylesford. This fact supports the opinion expressed on page 89, that in this locality there has been considerable erosion of the upper part of the Gault.

At Roydon, the most northern and eastern point from which we obtain samples of Gault, there is a slight increase in the amount of the coarse residue, which is here for the most part a quartz sand, the grains being distinctly of larger size. Those in the coarse residue from the bottom of the boring are no doubt derived from the underlying Carstone, but there is no evidence in the specimens from 15 feet and upwards that the grains are derived from the underlying rock, there are none of the well-rounded polished black and brown grains of Lydian stone so

common in the Red Chalk, though in the highest specimen there appears to be two types of quartz grains.

The specimens of Gault from Devizes contain a larger percentage of coarse residue than any of the other clays except those from Bindon, from which they differ considerably in the amount of glauconite. The coarsest part of the residue of No. 1 consists almost entirely of grains of this mineral, while the fine siftings contain 30 per cent., the remainder being chiefly fine sand and a few arenaceous foraminifera. There is a tinge of green in the specimen of the clay, but the colour of the residue is dark grey. This clay seems to closely approach a "Green Mud" in its composition. In No. 2, taken ten feet above the first, the amount of glauconite is not so large, the coarse residue consisting of very fine sand grains with 12 per cent. of glauconite. Both these residues are therefore distinguished from all others except two by the relative amount of glauconitic grains.

The exceptions are first the bed known as the Middle Greensand of Folkestone, the coarse residue of which (40·14 per cent.) is almost pure glauconitic grains with arenaceous foraminifera. This corresponds very closely indeed with the "Green Sands and Muds"[1] described in the Challenger Reports, and as in such deposits there described "from the shallower depths," the glauconite is associated with an amorphous greenish material like a tough clay.

In this connection, however, it may be mentioned that greenish material of a similar nature and associated with glauconitic grains occurs in the Upper Chalk of the Isle of Wight,[2] a deposit laid down in water probably of considerable depth.

In the Middle Greensand of Folkestone are many phosphatic nodules which strongly resemble that taken from the outer edge of the Agulhas Bank[3] in 150 fathoms of water, and figured on plate 22, fig. 1. of the Challenger Report.

They are of dark brown phosphate, which is soluble in hydrochloric acid, and imbedded in this material which forms a cement are glauconitic mineral grains, foraminifera, and other ingredients of the rock, forming a nodule of very irregular shape.

A similar bed seems to have been passed through in the Gubblecote boring specimen 3, 197 feet, though the analysis does not give so large a proportion of glauconite.

Specimens from the west of England (Dorset and Devon) present characters which may be described as the reverse of those above mentioned. The amount of soluble material is here very small, and in some of the specimens there is really no amorphous matter, nearly the whole deposit consisting of definite though minute mineral particles.

In the extreme west, at Bindon, the amount of the coarse residue increases very considerably, the percentage rising from

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[1] Reports of Chall. Expedition. Oceanic Deposits, page 380.

[2] Geology of the Isle of Wight (Mem. Geol. Survey), page 78. This green matter has since been found at several horizons in the Lower and Upper Chalk.

[3] Oceanic Deposits, page 391.

19·59 per cent. at the base to 40·15 per cent. in the highest specimen. In point of size the grains are largest in specimen No. 2, but even in this 85 per cent. of the mineral particles passed through a sieve the meshes of which were ·13 m.m. square. In the remaining 15 per cent. the average size of the grains is about ·25 m.m., the maximum being more than 1 m.m. The glauconite present in these residues was estimated at not more than 10 per cent.

From the character of the residues and the high percentage of the coarser material in the specimens from the west of England, we may infer an approach to the shore line of the Gault Sea while the gradual lateral passage to the calcareous deposit in Norfolk would seem to indicate a gradual slope and deepening water.

The Gault, as a whole, may be compared with the Blue and Green Muds of modern seas, its upper part passing in some localities into a calcareous ooze.

The amount of detrital minerals separated from the main residue is less than that of the Blue Muds described in the Challenger Report, nor is the list of rock particles recognised so extensive, but the small quantity of the material in the residues examined probably accounts for this, and a more thorough examination would reveal a more striking resemblance.

The abundance of small Marcasite nodules in the Gault constitutes a difference between it and the Blue Muds, but these were formed probably after the deposition and consolidation of the mud. In size the mineral grains correspond with those of the Blue Muds; and if the size of these grains may be taken as an indication of the deepness of the water, then the depth of the Gault Sea must be greater than that usually ascribed to it.

Mr. F. Chapman, who has recently made a study of the probable depth of the Gault Sea as indicated by the Rhizopodal fauna arrives at a similar conclusion. He says, "From the foraminiferal data for each zone of the Folkestone Gault, to be referred to subsequently, we obtain a mean depth for the Lower Gault of 830 fathoms. In a similar way the Upper Gault gives a mean depth of 866 fathoms[1] (*See* p. 415.)

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[1] Natural Science. November, 1898, page 307.

Tabulation of Residues.

——	Percentage of Main Residue.	Percentage of Coarse Residue.	Total.	Soluble in Acid.
Folkestone.				
7. Pale-grey Gault, 3 feet below the Chloritic Marl, Bed XIII.	66·82	5·74	72·56	27·44
6. Pale-grey Gault, Bed XIII.	69·04	1·13	70·17	29·83
5. Bluish-grey Gault about 3 ft. above the Middle Greensand, Bed XIII.	66·18	·73	66·91	33·09
4. Base of the Middle Greensand, Bed XII.	38·20	40·14	78·34	21·66
3. Base of the Upper Gault, Bed IX.	59·19	·23	59·42	40·58
2. 15 feet from the base of the Gault, Bed II.	85·70	·52	86·22	13·78
1. 5 feet from the base of the Gault, Bed II.	86·33	·47	86·80	13·20
Burham.				
Pale Olive-grey Gault	56·59	·27	56·86	43·14
Aylesford.				
Pale-grey Gault, top of pit	56·71	·28	56·99	43·01
Blue-grey Gault, 6 feet beneath	71·10	·42	71·52	28·48
Bindon Cliff, Devon.				
3. ——	56·71	40·49	97·20	2·80
2. ——	51·76	45·77	97·53	2·47
1. ——	73·69	19·59	93·28	6·72
Devizes, Wilts.				
2. ——	83·42	13·19	96·62	3·38
1. ——	86·69	10·63	97·32	2·68
Bucks, Gubblecote Boring.				
6. 1 to 17 feet down	72·72	·79	73·51	26·49
5. 151 ,, ,,	52·16	2·95	55·11	44·89
4. 187 ,, ,,	62·21	·37	62·58	37·42
3. 197 ,, ,,	74·92	7·33	82·25	17·75
2. 210 ,, ,,	78·98	1·53	80·51	19·49
1. 222 ,, ,,	36·89	36·20	73·09	26·91
Bedfordshire.				
Arlsey, 6 feet below the Cambs Greensand	65·72	·17	65·89	34·11
70 feet below the Cambs Greensand	63·34	·20	65·54	34·46
Norfolk, Roydon boring.				
5. 8 feet down	29·89	·89	30·78	69·22
4. 11 ,, ,,	36·80	·40	37·20	62·80
3. 13 ,, ,,	34·51	·82	35·33	64·67
2. 15 ,, ,,	49·75	·23	49·98	50·02
1. 18 ,, ,,	36·17	59·07	95·24	4·76
Red Chalk, Hunstanton	6·67	15·01	21·68	78·32

List of Foraminifera, identified by Mr. F. Chapman in the washings of the samples described in this chapter.

No.	—	Folkestone. 5 feet from base	Folkestone. 15 feet from base	Folkestone. Base of Upper Gault	Folkestone. Middle Greensand	Folkestone. Just above Middle Greensand	Folkestone. 8 feet above Middle Greensand	Folkestone. 3 feet below Chloritic Marl	Aylesford.	Gubblecote. 197 feet down	Gubblecote. 187 feet down	Gubblecote. 151 feet down	Gubblecote. 17 feet down	Roydo	Arlsey Station.	Base Beart's Pit, Arlsey	Beart's Pit, Arlsey, 6 feet under Cambs. Greensand.	Culverhole	Devizes
1	Nubecularia nodulosa, *Chapman*	–	–	–	–	–	–	–	–	–	–	–	–	–	×	–	–	–	–
2	Spiroculina nitida, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	–	–	–	×	–	–	–	–
3	„ asperula, *Karrer*	–	–	–	–	–	–	–	–	–	–	–	–	–	×	–	–	–	–
4	Miliolina venusta, *Karrer*	–	–	–	–	–	–	–	×	–	×	×	×	–	×	–	×	–	–
5	„ Ferussaci, *d'Orb*	–	–	–	–	–	–	–	–	×	–	–	–	–	–	–	×	–	–
6	„ tricarinata, *d'Orb*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	×	–	–
7	Haplophragmium nanum, *Brady*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	×
8	„ nonioninoides, *Reuss*	×	×	×	–	–	–	×	×	–	–	×	–	–	×	–	–	×	×
9	„ latidorsatum, *Born*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	×
10	„ æquale, *Römer*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	×
11	„ acutidorsatum, *Hantken*	–	×	–	–	–	–	–	×	–	–	×	–	–	–	–	×	–	×
12	„ globigeriniforme, *P. & J.*	–	×	–	–	–	–	–	×	–	–	–	–	–	–	–	–	–	–
13	Ammodiscus incertus, *d'Orb.*	–	–	×	–	–	–	–	–	×	–	×	–	×	×	×	×	–	–
14	„ gordialis, *J. & P.*	–	–	–	–	–	–	–	–	–	–	–	–	×	×	–	×	–	×
15	Trochammina concava, *Chapm.*	–	–	×	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
16	Textularia gramen, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	×	–	–	–
17	„ complanata, *Reuss*	–	–	–	–	–	–	–	–	–	–	–	–	–	×	–	–	–	–
18	„ turris, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	–	–	–	×	–	–	–	–
19	„ trochus, *d'Orb*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	×
20	Tritaxia tricarinata, *Reuss*	–	–	–	–	–	–	×	×	×	–	–	–	×	–	–	×	–	×
21	„ pyramidata, *Reuss*	–	–	–	–	–	–	×	×	–	–	–	–	–	–	–	×	×	×
22	Spiroplecta annectens, *P. & J.*	–	–	–	–	–	–	–	–	–	–	–	–	×	–	–	–	–	–
23	Gaudryina oxycona, *Reuss*	–	–	–	×	–	–	–	–	–	–	–	–	–	–	–	×	–	–
24	„ pupoides, *d'Orb.*	×	–	×	–	–	–	–	–	–	×	–	–	×	–	–	–	–	–
25	„ filiformis, *Berth.*	–	×	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
26	„ dispansa, *Chapm.*	–	–	×	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
27	Bulimina Presli, *Reuss*	–	–	–	×	–	–	×	–	×	–	×	–	×	×	–	–	–	–
28	„ var. sabulosa, *Chapm.*	–	–	–	×	–	–	–	–	–	–	–	–	–	–	–	–	–	–
29	„ affinis, *d'Orb.*	–	–	–	×	–	–	–	–	–	–	×	–	–	–	–	–	–	×
30	„ pyrula, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	–	–	×	–	–	–	–	–
30a	„ brevis, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	–	–	×	–	–	–	–	–
31	„ obliqua, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	×
32	„ pupoides, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	×	–	–	–	–	–	–	–
33	„ d'Orbignyi, *Reuss.*	–	–	–	–	–	–	×	–	–	–	–	–	×	–	–	–	–	–
34	„ obtusa, *d'Orb.*	–	–	–	–	–	–	×	–	–	–	–	×	×	–	–	–	–	–
35	Bolivina textularioides, *Reuss*	×	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
36	Pleurostomella obtusa, *Berth.*	–	–	–	–	–	–	–	–	–	–	–	–	–	×	×	×	–	–
37	„ alternans, *Schwager*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	×	×	–	–
38	Lagena apiculata, *Reuss*	–	×	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
39	Nodosaria orthopleura, *Reuss*	–	–	–	–	–	–	–	–	–	–	–	–	–	×	–	–	–	–
40	„ tenuicosta, *Reuss*	–	–	–	–	–	–	–	–	–	–	–	–	–	×	–	×	–	–
41	„ lorneiana, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	×	–	–
42	„ raristriata, *Chapm.*	–	–	–	–	×	–	–	–	–	–	–	–	–	×	–	–	–	–
43	„ (Glandulina) humilis, *Röm.*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	×	–	–
44	„ (G.) mutabilis, *Reuss*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	×	–	–
45	Lingulina semiornata, *Reuss*		–	–	–	–	–	–	–	–	–	–	–	–	–	×	–	–	–
46	Frondicularia Fritschi, *Perner*	–	–	–	–	–	–	–	–	–	–	–	–	–	×	–	–	–	–
47	„ Ungeri, *Reuss*		–	–	–	×	–	–	–	–	–	–	–	–	×	–	–	–	–
48	Rhabdogonium excavatum, *Reuss*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	×	–	–
49	Marginulina Jonesi, *Reuss*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	×	–	–	–
50	Vaginulina recta, *Reuss*	–	–	–	–	–	–	–	–	–	–	–	–	–	×	×	×	–	–
51	„ truncata, *Reuss*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	×	–	–
52	„ Biochei, *Berth.*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	×	–	–
53	Cristellaria gaultina, *Berth.*	–	–	–	×	–	–	–	–	–	×	–	–	–	×	×	×	–	–
54	„ complanata, *Reuss*	–	–	–	–	–	–	–	–	–	–	–	–	–	×	–	–	–	–
55	„ vestita, *Berth.*	–	–	–	–	–	–	–	–	–	×	–	–	–	–	–	×	–	–
56	„ gibba, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	×	–	–
57	Polymorphina gibba, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	×	–	–
58	„ „ var. acuplacenta, *Jones & Chapman*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
59	„ fusiformis, *Römer*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
60	Ramulina aculeata, *Wright*	–	–	–	×	–	–	–	–	–	×	×	–	–	×	×	×	–	–
61	Globigerina cretacea, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	×	–	–	–	×	×	–	–
62	Anomalina ammonoides, *Reuss*	×	–	–	×	–	–	–	–	–	×	×	–	–	×	×	×	–	–
63	„ rudis, *Reuss*	×	–	–	–	–	–	–	–	–	–	–	–	–	–	–	×	–	–
64	Pulvinulina spinulifera, *Reuss*	–	–	–		–	–	–	–	–	–	–	–	–	–	–	×	–	–
65	Rotalia Soldani, *d'Orb.*, var. nitida, *Reuss*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	×	–	–	–
66	Truncatulina lobatula, *W. & J.*	–	–	–	–	–	–	–	–	–	–	×	–	–	–	–	–	–	–
67	Verneuillina triquetra, *Brady*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	×
68	„ variabilis, *Münst.*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	×	–
69	„ sp.	–	–	–	–	–	–	–	–	–	–	–	–	×	–	–	–	–	–

CHAPTER XXV.

MICROSCOPIC STRUCTURE AND MINERAL INGREDIENTS OF THE SILICEOUS BEDS (GREEN SANDS).

By William Hill.

What has hitherto been known as the Upper Greensand includes a much greater variety of deposits than the beds which are known as Gault. Although they are all more or less sandy or gritty, the proportion of quartz sand is in some of the beds very small indeed. Hence it will be convenient to describe the Upper Greensand rocks under three separate heads. First we shall take the fine-grained beds which are known by a number of names, such as malm-rock, malmstone, firestone, hearthstone, and in France as "gaize." These beds are generally confined to the lower portion of the Greensand, but sometimes make up the greater part of it, as in Hampshire, Surrey and Berkshire. Secondly the structure of the layers and nodules of chert and of the associated sponge beds will be described. Lastly the composition of some glauconitic sands and sandstones will be briefly noticed.

Malmstones and Micaceous Sandstones.

The term malm-rock or *malmstone* is applied to a rock which consists principally of silica in a colloid condition, and contains only a small proportion of quartz-sand, seldom more than 10 or 12 per cent. Firestone, hearthstone and burrystone are varieties of malm, generally more or less calcareous. But from a typical malmstone there is every gradation to a micaceous sandstone with 40 or 50 per cent of quartz, though still containing much colloid silica.

The *gaize* of French geologists appears to be the exact counterpart of our malmstone, and M. Cayeux[1] has shown that this kind of rock is not confined to one horizon nor even to the Cretaceous system, but occurs in the Eocene and also in the Jurassic. He has given a definition of gaize which would apply equally well to our malmstones, and he proposes that its varieties should be described in accordance with their dominant mineral ingredients, as gaizes argileuses, gaizes calcariféres, gaises quartzeuses, which we might translate as argillaceous, calcareous, and quartzose malmstones.

Where Gault and Greensand are fully developed there is a gradual passage from a sandy micaceous marl or clay to a sandy micaceous stone. Where this passage can be followed, as at

[1] Études Micrographiques, par L. Cayeux. Lille 1897.

Merstham and Betchworth in Surrey, near Wouldham in Hants, near Devizes and Westbury in Wilts, and near Woolstone in Berkshire, samples show that it is marked by a decrease in the quantity of pyritous and argillaceous matter, and by the incoming of a peculiar form of silica which imparts to a thin slice of the rock a clearer and more transparent aspect. In the localities above-mentioned the beds pass into pure siliceous or calcareous malms, but in South Wilts, the Isle of Wight, and Dorset they pass into quartzose malm or into soft micaceous sand with little colloid silica.

The malmstone of Surrey and Hants is a fine-grained rock, consisting principally of minute particles of silica in a granular or globular condition, together with a large number of the spicules of siliceous sponges. Fine quartz sand, flakes of mica, and small grains of glauconite are the other principal ingredients. Foraminifera and small fragments of shell are often present in small quantity. There is also a certain amount of very fine amorphous material, the silicate of alumina already described, together with fine calcareous particles and pseudo-coccoliths.

The rock is sometimes very soft and friable, sometimes firm and coherent, the latter state being produced sometimes by the aggregation and felting together of the siliceous granules and sponge spicules and sometimes by the infiltration of a calcareous crystalline cement.

The colour of the Hampshire malmstone varies from dull-grey or greyish-brown to light whitish-grey; the darker varieties usually contain a larger proportion of the fine amorphous matter, while the whitish rock is either a pure siliceous or a siliceo-calcareous malm.

In Wiltshire there are generally some beds of compact malmstone above the Gault, of a dull-grey colour and often calcareous, and these beds pass up into a very sandy malm or quartzose gaize, in which grains of quartz and glauconite are more numerous than the sponge-spicules and granular silica. This is the micaceous sandstone of Devizes in which so many fossils have been found, for it is a curious fact that where organic silica is abundant, the remains of other organisms are rare.

As it is not possible to break down specimens of malmstone completely so as to separate its constituents, our knowledge of its structure must be gained from the examination of thin sections and from such portions as can be isolated by the action of chemical reagents. The following is a more particular account of the component materials.

Detrital Minerals.

Quartz is the most abundant mineral of the malmstones and micaceous sandstones. It occurs as angular, subangular, and sometimes well-rounded grains, for the most part clear and glassy. The proportion of quartz-sand varies a good deal in the specimens examined; those from Hants were estimated to

contain from 5 per cent. to 15 per cent., in Surrey and Sussex there is about the same proportion. In Bucks and Oxon the range was from 5 per cent. at Pitch Green, Risboro', to 25 per cent. at Pyrton, near Watlington.

A specimen of the micaceous sandstone of Devizes contains at least 50 per cent. of sand, another from a lower horizon about 15 per cent.

As a whole, the specimens from the outcrop of the main escarpment of the Cretaceous Rocks contain more sand than those of the North and South Downs, with the exception of examples from Eastbourne, which are very sandy, and can hardly be called malmstone.

There is considerable variation also in the size of the grains. In the malmstones of Surrey, Sussex, and Hants, the average size of the larger grains in all specimens examined was ·06 m.m. with a maximum of ·11 m.m.; in the specimens from Bucks there was greater variation in the size of the sand grains, the maximum average being in that from Pyrton, ·15 m.m., the smallest at Pitch Green, ·04 m.m. In the micaceous sandstones of Devizes the average size varies from ·18 m.m. to ·12 m.m., the grains being decidedly larger than those further east. Mica occurs in nearly every specimen; it can only be recognised in thin sections when the flakes are cut transversely, and it is not possible to estimate the proportion of this mineral.

It is probable that felspars, tourmaline, rutile, zircon and other minerals also occur in the Greensands, but they have not been specifically identified.

Secondary Minerals.

Of the secondary minerals glauconite occupies an important place. The grains are similar to those already described in the Gault, and have the usual roughly mammillated, furrowed, and irregularly outlined contour.

It is commonly seen infilling the canals of sponge spicules or replacing altogether the silica of the spicule. Fragments of these spicular casts are very abundant in some beds.

The estimated amount of the grains varies from 20 per cent. in the micaceous sandstone of Devizes, to 1 per cent. or even less in some malms. Their size corresponds on the whole with that of the quartz grains. Iron-pyrites or marcasite is far less common in the Upper Greensand than in the Gault; small nodules occur in many Malms examined, with small masses of brown ferruginous material.

Organic Elements.

Tests of Foraminifera are seen in almost every thin section of the malmstones. They are never conspicuously abundant, and form a very small part of the deposit.

Textularians, Globigerina, and a variety of Rotaline forms may be made out. The cells are filled either with calcite or with silica in chalcedonic or colloid condition, or with glauconite, and sometimes with the amorphous material of the matrix. It

is noticeable that where sponge spicules are abundant there are few foraminifera.

Shell fragments do not occur commonly in the purer kinds of malmstone, but in the more friable sandstones a few fragments may be seen, chiefly prisms of Inoceramus.

Sponge spicules are common in the malms; they are not equally dispersed throughout the rock, but are more abundant in beds which may be recognised either by having harder portions of the rock which weather out prominently, or by the occurrence of bluish-grey siliceous concretions, which occur in layers like flints, but, unlike flints, are usually inseparable from the surrounding matrix.

All four of the chief divisions of sponges are represented. Dr. Hinde, in his Memoir on the Sponge remains of the Upper and Lower Greensand, gives a description of the aspect and condition of the spicules of the sponge beds, of which the following is a brief resumé [1]:—

The spicules are exclusively those of siliceous sponges, the silica of which has undergone various molecular alterations and now presents gradations between the amorphous or colloid and the crystalline state.

The silica of the spicules in the sponge beds is now in the following mineral condition—either in the amorphous or colloid state; or crypto-crystalline, like chalcedony; or crystalline; or replaced by glauconite or other silicate, or by crystalline calcite; or the silica of the spicule may be dissolved away, leaving only a mould of the original spicule, or a cast in glauconite or silica of the spicular canal.

The external appearance of those spicules which retain their silica in the amorphous condition, and which are the more perfectly preserved, is milky-white or opal by reflected light, transparent by transmitted light. The spicular walls are traversed in all directions by minute curved lines, which under high powers can be resolved into incomplete elliptical rings. In no instance does the spicular canal exist as a hollow tube, but is always fiilled with glauconite, silica or a ferrous compound. The infilling material being of a more stable nature than the spicular wall, the wall is frequently dissolved, while the material infilling the canal remains and might be mistaken for an original spicule.

Spicules which are now of chalcedonic and crystalline silica have a different aspect from those in which the silica is colloidal. They appear like ground glass, and their surface has a rough, eroded appearance.

Sometimes the silica of the spicule is entirely replaced by glauconite or by calcite.

Globular Colloid Silica.

Associated with the spicules in the Malmrock is a large amount of silica in the colloid state in the form of discs or globules, to which Dr.

[1] Phil. Trans. 1885, part 2, p. 425.

Hinde, in his Memoir on the Sponge Beds of the Upper and Lower Greensand, thus refers[1]:—

"The colloidal silica of the Sponge beds occurs in the form of minute granules . . . and also in globular form, that is to say, in very minute bodies with circular outline though not strictly of spherical form." "While single bodies have a circular outline where several coalesce, their margins become truncated at their point of contact. Frequently these bodies are clustered around residuary spicules and attached to the solidified canals of spicules." In the commonest forms there is a marginal ring about one-sixth of the diameter of the globule which seems faintly striate, or "the surface is covered with faint striæ which radiate from an indefinite central granule." The smallest and simplest globules consist of perfectly clear silica without striæ or granule (see Plate, Figs. 1 and 2, p. 361). They vary in size, the smallest being ·0014 m.m. diameter, and from this there are all graduations in size to bodies ·045 m.m. in width. The globules are without action on polarised light, and readily dissolve in a solution of caustic potash.

When, however, thin sections of malm or some of the micaceous sandstones are viewed under the microscope, there will appear in many specimens a considerable amount of colloid silica in which the globules or discs are not so perfectly formed. Thus, when a thin section of malmstone from Sutton Mandeville, in the Vale of Wardour, is viewed by transmitted light with an objective of two-thirds of an inch focus, there can be seen minute granules glassy or slightly opalescent with a faint rosy tinge; though scattered indiscriminately through the mass of the rock, they are distinctly more numerous in defined but irregular areas. They are so intimately mixed with the amorphous material, and so finely outlined, that it is impossible to separate them from it, and they become lost among the minute particles of the matrix of the malm if a higher power is used. Were it not for analogy in the next specimen to be described, the relation of these minute particles to the globules of colloid silica might be overlooked. There are no spicules in this slide.

In a second specimen from the same locality but at a higher horizon granules of exactly the same kind occur, and the matrix consists very largely of them. They have in this section a clearer outline, and can be recognised with a lens of ¼-inch focus, and with them are associated minute globules, none larger than ·001 m.m. Both globules and granules seem to have the same faint rosy tint as before, and behave, both optically and chemically, like colloid silica. An Analysis of this rock is given on page 327.

We have here in fact, but on a much smaller scale, features analogous to those specimens where globular colloid silica is more perfectly developed. As in the case of the larger globules, the irregularity in the shape may be due to the close approximation of each globule during the process of formation. There are a few spicules in this slide, their silica is in the colloid state, while one or two glauconitic casts of spicular canals indicate the dissolution of others.

A further stage in the development of the globules is seen in a specimen from Compton Basset in Berks. Here there is no difficulty in recognising both the irregularly shaped granules or the globules, and their presence gives the section a curiously mottled aspect when viewed by transmitted light. The irregular granules of colloid silica and more or less perfect globules are always so intimately mixed with the matrix, that it is very difficult to obtain a clear view of them or separate them from it. When the edges of the section are examined, or detached portions of it, with an objective of ¼-inch focus, the particles are seen to be glassy, opalescent, very finely granular, ragged and ill-defined in outline, and where superimposed on each other exhibit a faintly rosy-brown tint. The globules, which occur in considerable numbers, are perfectly plain, having neither nuclear spot nor ornamention of any kind, but agree in all other essential particulars with the simplest forms described by Dr. Hinde.

From the stage described above, thin sections of malm exhibit all

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[1] Phil. Trans. Roy. Soc., 1885, part ii., p. 403.

gradations in the character of colloid silica to the perfectly formed globules described by Dr. Hinde, but in all cases there seems a direct relation between the development of the globules and the amount of spicules occurring in the rock as a whole. M. Cayeux in his review of the varieties of the "Gaize" notes this variety of colloidal silica under the designation of "Silica gelatinoide."[1]

M. Cayeux believes also that silica in the colloid state was obtained not only from the spicules of sponge, but also from the decay of the amorphous silicate of alumina which occurs in the "Gaize."

The hard concretionary masses of bluish-grey colour which occur in layers or form the harder parts of malmstone, contain a larger amount of spicules and colloid silica than the softer surrounding rock. The silica is in well-formed globules, and such specimens frequently show the earlier stages of the passage of the globular silica to crystalline chalcedony, as will be described shortly.

Sponge Beds and Cherty Concretions.

As might be expected from the variable aspect of the beds which compose the upper part of the Greensand, there are great differences in their composition and structure. Some beds consist almost entirely of mineral grains (quartz, glauconite and mica), which are sometimes cemented together by calcite into a calcareous sandstone, but there are others in which the remains of siliceous Sponges occur in such quantity that Dr. Hinde has claimed them as deposits of organic origin and has called them "Sponge Beds."

These "Sponge Beds" do not, however, consist of Sponge-skeletons, either complete or partially complete, but are made up principally of the minute detached spicules of various kinds of Siliceous Sponges. Dr. Hinde writes[2]:—"The deposits appear to have been produced by the disintegration of the skeletons of numerous generations of sponges which have successively lived and died in the same areas in which the deposits occur. On the death of the animal the soft tissues by which its skeleton was held together would rapidly decay, and its individual particles would thus become detached from each other and be scattered over the surface of the sea-bottom. As a result of this the fossil sponge beds consist of a heterogeneous mixture of the skeleton-spicules of various kinds of Sponges. Under exceptionally favourable conditions of preservation the minute spicules are now met with in a loose detached condition, not unlike that in which they may be supposed to have been present at the sea-bottom soon after the death of the animal; but as a general rule they are now amalgamated with the inorganic materials of the deposits into hard beds of rock, and they have suffered partial or complete solution and replacement by calcite, glauconite and iron peroxide."

Beds consisting largely of sponge-spicules occur in the higher part of the Malmstone of Surrey and Hampshire,

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[1] Contribution à l'Étude Micrographique des Terrains Sédimentaires, par L. Cayeux, page 63. (Lille, 1897.)

[2] On Beds of Sponge-remains in the Lower and Upper Greensand. Phil. Trans. Roy. Soc., 1885, p. 403. Figs. 1 and 2 of the accompanying Plate are taken from Dr. Hinde's Plates, xl., fig. 3, and xlv., fig. 19.

and in the Chert Beds of Wiltshire, Dorset and the Isle of Wight. Some of them might be termed spiculiferous sand or silt, others have the aspect of a coarse granular sandstone when seen in the quarry, but really consist largely of felted masses of spicules (chiefly of large megamorine Lithistid Sponges). Material of this kind has been called "sponge rock" by Dr. Hinde, but we think a better name might be found.

A mass of such rock 10 feet thick, exposed in a quarry near Shute Farm, Warminster, is thus described by Dr. Hinde (op. cit. p. 420):—"The rock . . . is of a whitish appearance, and consists of silica, both amorphous and as chalcedony, calcite, a small quantity of mica and grains of glauconite and quartz. It is filled with spicules of relatively large size; . . . these spicules are of amorphous silica and are entirely negative between crossed nicols, though their canals are usually infilled with chalcedonic silica or with glauconite, and the transparent siliceous matrix in which they are embedded is also chalcedonic. The spicules are in such profusion in some of the beds that they form distinctly marked thin white parallel layers, with intermediate layers which, from the larger proportion of glauconite grains in them, are of a greenish tint. These parallel layers must have been thus arranged at the time the beds were forming, and they indicate the disintegration of the sponges and the mingling of their spicules before they were buried under fresh deposits. The perfect condition of the spicules likewise indicates that they could not have been drifted to any extent over the sea-bottom."

In this and other sponge-beds layers and nodules of chert are of frequent occurrence.

Similar rock, having a granular aspect, occurs in quarries at and near Maiden Bradley, and Dr. Hinde thus writes of a sample sent to him from this locality:—"The sponge remains filling the rock are detached spicules of megamorine Lithisthid and Tetractinellid sponges which have been disintegrated. The spicules are still of colloid silica in the globular condition or filled with the peculiar curved C-like markings. Their canals are filled with solid glauconite or allied greenish mineral. The only other organisms recognised are Foraminifera (*Globigerina*, *Rotalia*, and *Textularia*), and to these the calcareous constituents are mostly due. The minerals of the rock are quartz-grains, globular silica, glauconite-grains and mica-flakes, also calcite. The quartz-grains are mostly small and angular; an interesting peculiarity about them is that many have attached to their surfaces the small siliceous globules derived from the disintegration of the spicules, in some cases covering the quartz grains."

With such sponge-rock there often occur layers of a fine whitish or greyish-white silt. We only use the word silt for want of a better one, but the material consists largely of spicules (perfect and broken) and of globular silica, with variable quantities of fine quartz-sand and of silvery mica. Glauconite is generally present in such small quantity that it gives no tint to the deposit.

Between the more spiculiferous layers which may properly be designated as "sponge beds" the aspect of the rock, when viewed under the microscope in thin sections, varies according to its predominating constituents, and is not all alike throughout.

In some cases crystalline calcite permeates the whole rock, intimately intermingling with the spicules and colloid silica. At Merstham, and Puttenham in Surrey, at Binstead and Dippenhall in Hants, and in other places there exist courses of distinctly calcareous rock. Thus specimens of a hard bluish-grey rock between two well-marked sponge-beds at Puttenham consist almost entirely of coarsely granular calcite, and though the rock doubtless contains a certain amount of silica—for sponge-spicules and residuary spicules of glauconite can be seen in it—this is completely masked.

At Dippenhall (for section of this quarry see page 109) there is a bed of rock four feet six inches thick which seems almost entirely granular crystalline calcite; beneath is a line of doggers, in which the partly crystalline and partly amorphous colloid silica with spicules indicate a "sponge-bed"; then comes a layer in which spicules, though abundant, are not pre-eminently so, the material containing much amorphous inorganic matter glauconite, sand grains, &c. Below this follows a bed six feet six inches thick, almost purely siliceous, consisting chiefly of fine amorphous colloid silica, somewhat similar to that described on page 356, much globular colloid silica and sponge-spicules: it is a well-defined "sponge-bed" though not crystalline. Other similar instances could be quoted. The more calcareous of the beds described above are quarried for building material and road mending.

Not only do moderately thick beds containing much calcite exist between the sponge-beds, but some of the dogger-like masses which at first glance might be thought a repetition of spongeous layers are really calcite. Thus at the Boreham quarry near Warminster there is a line of doggers consisting entirely of broadly crystalline calcite, with here and there a spicule, but with no colloid silica optically visible.

In the central and western part of the Isle of Wight sponge-beds occupy the same position as in Wiltshire, At its eastern end they are not so evident, though layers of doggers with sponge structure occur. Between them the material of the rock is fine silt consisting of the amorphous silicate of alumina with mineral grains chiefly quartz and some glauconite, grains of the last-mentioned mineral often occurring in considerable quantity. There are very few spicules and no colloid silica.

The layers of chert which form so conspicuous a feature of the sponge-beds consist of silica, which is wholly or partially in a crystalline condition, and includes more or less of the organic and inorganic constituents of the deposit.

The term chert is applied not only to the beds of clear glassy crystalline silica which are a feature of the higher beds of the Upper Greensand, but also to the dull bluish-grey and far less crystalline masses which occur at this and at somewhat lower horizons.

These different varieties of chert are due partly to varying amounts of silica in a colloid condition, and partly to the impurities which may be included within it.

Thus, if a section of one of these bluish-grey concretions be examined, it will be seen to consist of sponge-spicules, globular silica, and a certain amount of amorphous material with other ingredients of the rock, such as sand and glauconitic grains, occasionally a few foraminifera, &c.

There may be great variation in the condition of the spicules; some may have the silica of their walls still in the colloid state, in others the walls may be dissolved and only casts of the spicular canal remain in glauconite, or in a stable siliceous substance which behaves optically as chalcedony; in a calcareous malm, residual spicular canals may be of calcite.

The globules of silica will appear finely but distinctly outlined and none of their character is lost.

But the whole mass is permeated with a clear glassy substance which here and there exhibits a faint crypto-crystalline structure, and is silica probably derived from the dissolution of some of the spicules. If a thin slice of such a specimen be boiled for a short time in caustic potash, many of the spicules and much of the globular silica will disappear; the remainder is seen to be partly crystallised chalcedonic silica, which here and there has protected globules or spicules from the action of the potash.

Here then we have an example of what may be termed, immature chert, a rock indurated with silica, possibly derived from the dissolution of sponge-spicules, which seems slowly passing to a more crystalline condition.

Though these cherty nodules usually contain more spicules and globular colloid silica than the surrounding rock, no reason can be given for the commencement of crystallisation around one particular point; it is quite possible to find beds, in which the quantity of globular silica and sponge-spicules is quite as large yet the rock remains unaltered.

The purest black crystalline chert presents a very different aspect. Thin sections of this, when viewed by transmitted light, are seen to have a broadly fibrous, crystalline appearance, polarising with brilliant colours, thus differing greatly from the minutely crypto-crystalline structure of flint. The fibres radiate from a number of common centres, and, interfering with each other, produce an irregular fan-shaped arrangement. Here and there areas occur in which the structure is clear and glassy; such areas behave optically like quartz, polarising with brilliant colours, and exhibiting a definite crystalline structure. Such areas cannot be confounded with an accidental accumulation of quartz grains. Though fragments of pure black chert may be obtained of some size, it is usually not difficult to find traces of sponge spicules.

Between pure black chert and the opaque blue-grey concretions just described there is every gradation.

In the bluish-grey crystalline yet opaque chert, the silica of the matrix is fibrous chalcedony, and the opacity appears

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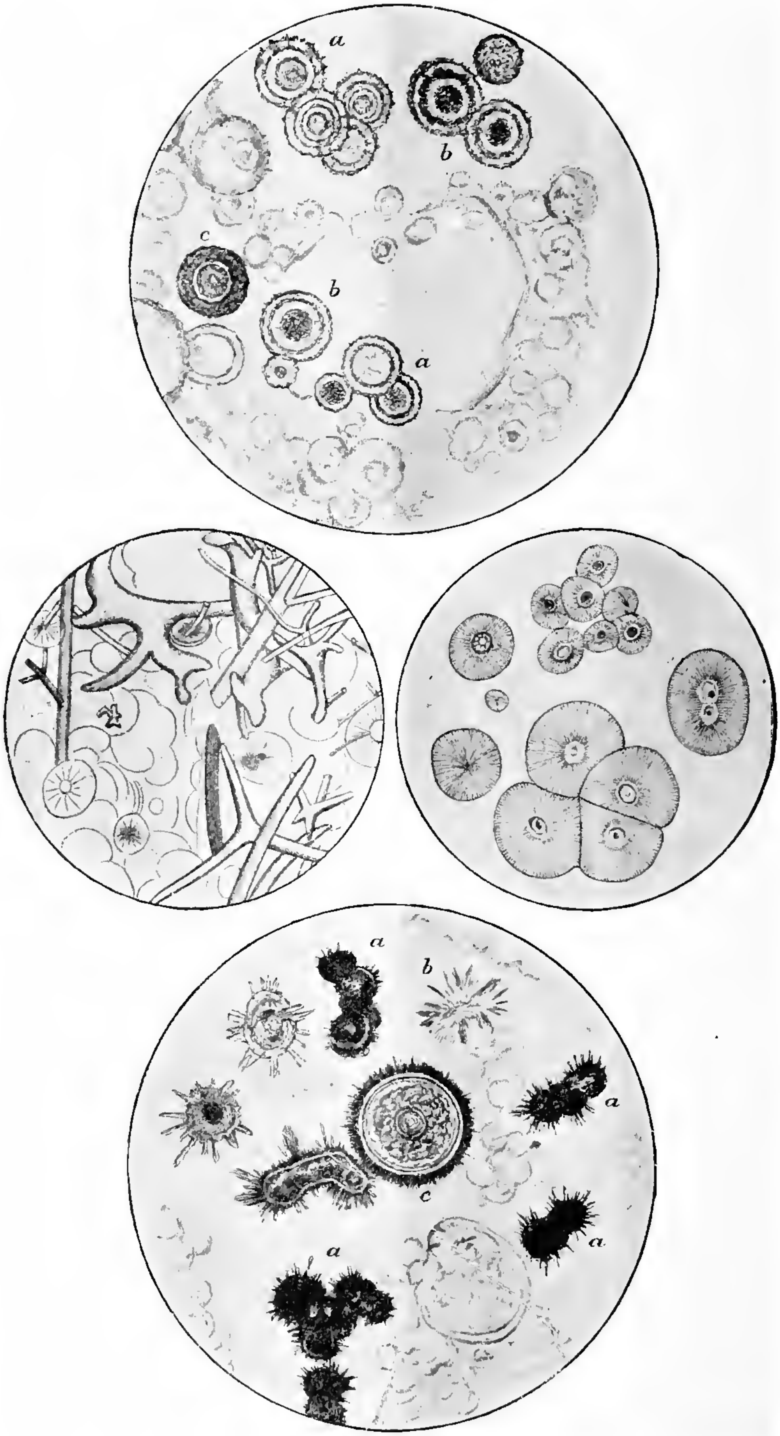

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4

MICROSCOPIC SECTIONS. UPPER GREENSAND.

to be produced by the masses of partly altered globular silica, the sponge spicules, and other included material. The clearer, but dirty-looking chert contains in the crystalline matrix much opaque organic matter, sand grains and glauconite &c., and not infrequently an oxide of iron in a very fine state of division is distributed through the mass. Sometimes the chert contains definite calcite-particles, apparently fragments of shell, but most frequently it is the masses of globular silica and sponge-spicules which form the cloudy patches in otherwise comparatively clear chert.

We have already said that when a thin slice of opaque bluish-grey chert was boiled in caustic potash, globules and sponge spicules with their silica in the colloid state were dissolved.

In some specimens of chert the spicules and globules have been dissolved out naturally as in that from Bugley near Warminster and Fiddington south of Devizes; the silica having probably gone to augment the chalcedonic matrix; such rock, which is very light in the hand, shows only the casts of the spicules and globular silica which once existed in it. Crystalline concretions of a cherty nature but of different character to that above described not infrequently occur between marked sponge beds. Thus at Boreham quarry are two beds which are practically layers of sand cemented by crystalline silica. The proportion of sand was estinated at 80 per cent.; few spicules were to be seen, but between the sand-grains globular silica was abundant.

Though sponge spicules occur in every specimen of chert we have examined they are not abundant in all, and from the evidence of many sections examined there seems good reason for believing that the silica of the spicules gradually changes from the colloid to the chalcedonic condition and becomes absorbed as it were into the chalcedony; in the process the outline of the spicule frequently becomes lost or is only feebly outlined, so that even cherts, which are now comparatively free from spicules, may have originated from their previous existence.

The accompanying Plate illustrates:—

Fig. 1. Section of Sponge-rock showing Sponge-spicules and globules. (G. J. Hinde.)
Fig. 2. Globules of colloid silica. (G. J. Hinde.)
Figs. 3 and 4. The gradual change in the appearance of the globules in the process of their apparent absorption into the chalcedonic matrix. *c* in Fig. 4 in a Sponge-spicule.

Not only does the colloid silica of the spicules seem to pass directly into the chalcedony of chert, but that of the globules also.

To see this it is necessary to examine a series of thin sections of cherty nodules from the opaque bluish-grey variety to those in which the silica is crystalline chalcedony. It will then be seen that the general aspect of the typical unaltered globule or disc viewed by transmitted light in a thin section of partly crystalline chert is that of a circle delicately outlined, its edges, internal markings and ornamentation sharply defined. The first indication of alteration is an increasing

> distinctness and a broadening of the outer rim (Fig. 3a), which seems due to a kind of granulation; noticeable granulation of the interior succeeds (Fig. 3b), until semi or almost complete opacity is reached (Fig. 3c). This alteration is frequently accompanied by a brownish discoloration as though by infiltration of iron. The aspect of the now nearly opaque globule is white and pearly by direct light. It is difficult to say what happens next. Some of the globules which have reached this stage are certainly hollow, in some it can be indistinctly seen by transmitted light that they are filled with fibres arranged radially from a common centre. Around the periphery of the globule may now be seen opaque hair-like projections (Fig. 4a) which roughly speaking align with the fibres of the chalcedonic matrix. Then the boundary of the globule becomes indistinct, a crystallisation of the interior seems to proceed with a gradual decrease of opacity, and finally a mere blur (Fig. 4b) in the crystalline chalcedony indicates the position of the globule.

This description applies particularly to those bodies of colloid silica which appear to be spherical.

In the case of those which appear to be discs much the same phenomena occurs, viz., accentuation of outline, interior granulation and discoloration, hair-like projections from the periphery, and the gradual and final disappearance of form in the surrounding chalcedony.

Not only do single globules exhibit this phenomenon, but whole masses of them seem to undergo a similar change.

All chert contains globules or traces of them, as well as spicules, The result of the examination of a series of thin sections, from the opaque and what may be termed immature chert to the mature pure black variety, leads me to believe that though a certain amount of silica may be interchanged from one bed to another in solution by percolating water, the greater part has been transformed *in situ* from the colloidal condition of the spicules and globules into that of crystalline chalcedony.

A case of the possible transference of silica from one bed to another occurs in the very sandy chert noted on page 361. There are practically no spicules, and though the silica may have been introduced during the formation of the bed, it seems also possible that the cementing material may have been carried down by percolating water. There are many globules between the sand-grains, and these are in all stages, from the mature and perfect globule to that which seems gradually merging into the chalcedony; many are hollow, and doubtless all are contributing or have contributed to the crystalline cement.

From the study of the "Sponge Beds" it is clear that at this period Sponges existed locally in exceptional abundance. The shedding[1] of their spicules, their death, and the decay of their tissues, and the accumulation of a fine sediment around them produced a deposit highly charged with organic silica in the unstable colloid state.

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[1] See Sollas, A Contribution to the History of Flints. Proc. Roy. Soc. Dublin, vol. xii., part i., 1887; and also Oceanic Deposits, Report of the Challenger Expedition, page 284.

That spicules are dissolved in sea water, there is abundant evidence to prove, but we have already expressed our opinion that the globular colloid silica was formed in siliceous oozes,[1] the silica of dissolved or partly dissolved spicules contributing to its formation though the precise chemical actions which took place are by no means clear.

Examination of cherts leads one to believe that accumulations of siliceous material, consisting almost entirely of sponge spicules and colloid silica, existed at the horizons now occupied by the chert, that a large part of this material passed into the form of gelatinous silica, and that on the elevation and consolidation of the deposit this silica passed into chalcedony and formed the various kinds of chert.

From evidence given in the preceding pages it would appear that this crystallisation took place *in situ*, and that some of the phenomena connected with its stages can be still followed under the microscope. Many years ago Prof. Sollas pointed out to one of us specimens of large *Cytherea* and *Cyprina* from the Blackdown Beds, the inside of which were practically filled with chalcedony the surface of which was flat, and he explained this by supposing that the shells had caught the silica as if they were cups or plates in the sand, the silica remaining in the shell and becoming a colloid mass, which afterwards crystallised into chalcedony. There was in all probability concentration of the silica by the escape of water through the shell, the shell being replaced by silica in the process. Many spicules and much globular silica have been and perhaps are still being dissolved by percolating water, but such silica is probably carried away in solution, and we doubt whether any of it is added to the existing cherts, though there is a possibility of this occurring under favourable circumstances.

No doubt much of the calcareous material which may have been intermixed with the original sediment has also been removed by percolating water, but there is no evidence to favour the view that the space now occupied by chalcedony ever consisted wholly of calcite, or that the rock was a limestone which has been altered by a direct process of replacement.

We entirely agree with Dr. Hinde's statement (op. cit. p. 420), that the cherty portions of a sponge-rock "were originally as [fully] filled with perfect spicules as the siliceous rock [or sandstone] into which they pass, and that the difference results from the solution of the amorphous silica of the walls of the spicules, and its redeposition in the chalcedonic condition to form the chert."

3. Green Sands and Glauconitic Rock.

The highest beds of the Upper Greensand are generally sandy or glauconitic sand, sometimes cemented by calcite into sandstones, but the size of the grains varies according to locality.

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[1] Quart. Journ. Geol. Soc., vol xlv., pages 415 to 420.

Glauconitic sands and sandstones occur both above and below the Chert beds of Wilts, Dorset, Devon, and the Isle of Wight; their chief constituent is coarse quartz sand, with fragments of felspar and mica, but large glauconitic grains are abundant. The cementing material of the sandstones is crystalline calcite, and in the highest beds no sponge spicules or globules of silica occur. Much soft rock of an equally sandy nature occurs at the Cann quarry near Shaftesbury, and the highest beds of the Greensand below Melbury Hill are of similar but finer grain. The highest beds of Surrey are somewhat soft, and consist chiefly of fine inorganic material and much calcite in fine particles. Mica is often abundant, the rock sparkling with mica-flakes, and glauconite-grains are sufficiently numerous to give the rock a green-grey tint.

We have not examined minutely the soft green glauconitic sands of Bucks or Berks, nor any specimens of the highest part of the Upper Greensand along its outcrop at the base of the South Downs except at Eastbourne. Here a sandy, micaceous and slightly glauconitic rock with a few sponge spicules, but hardly a Malm, passes down into a firmly compacted Greensand in which the grains of glauconite form 75 per cent. of the mass.

Detrital Minerals.

Some of the detrital minerals of the higher beds of the Upper Greensand have already been alluded to. Quartz is by far the most abundant. Fragments of felspathic rock are clearly recognisable in the coarse sands and sandstones of the West of England, and in the dust from various specimens tourmaline, zircon and rutile can be seen. Mica is almost always present. As in the Malmstones, all specimens which contain the coarsest grains come from the West of England. Those from a rather soft bed at Cann quarry near Shaftesbury, from Crockerton and from the upper part of the Upper Greensand at Mewp Bay average ·4 m.m. in their longest diameter. Those in the sandy beds at Boreham near Warminster average 2·5 m.m ; in the calcareo-siliceous sandy rock of Stert the average is about ·2 m.m. In the sponge beds (chert) of Warminster and Devizes their size is about ·15 m.m. From a specimen 4 ft. below the Chloritic Marl near Alton the average is ·13 m.m., and the micaceous beds at the top of the Greensand near Godstone about ·1 m.m.

In quantity it was ascertained by actual experiment that the bed at Cann quarry contained 74 per cent. of mineral grains, chiefly quartz, with some glauconite and mica and probably some felspar. The estimated amount of quartz-sand in the sand-rock at Crockerton is 80 per cent.; in the sandy beds, Stert, 25 per cent. to 60 per cent. In the sponge-beds the amount of quartz is not large, and unless the grains are so masked by the chalcedony as to be invisible the quantity is frequently not over 5 per cent., rarely 15 per cent.

The following are notes on a few interesting specimens, slides of which were prepared at the Geological Survey Office and sent to me for examination:—

No. 1. *Sandstone No. 7, from Grafton cutting Wilts* (*see* p. 264).—By transmitted light and under a ⅔ inch objective this rock is seen to consist mainly of mineral grains, chiefly quartz, with some mica and a few grains of tourmaline, zircon, &c. The proportion of such mineral grains is about 60 or 70 per cent., and there is besides about 7 per cent. of glauconite grains.

There are a considerable number of Foraminifera in the slide chiefly *Globigerina* and *Textularians*, and there are many small calcareous particles.

The rock contains also a number of sponge spicules; many of these consist of silica in the usual colloid state, but in others the spicular walls have been replaced by calcite. In some cases the canal only is filled with calcite, but in others the whole spicule seems to have been so replaced, again in others the walls are calcite while the canal is filled with globular silica, or with silica in which faintly marked indications of chalcedonic structure can be seen. The canals of other spicules are filled with glauconite.

The cementing material is a curious mixture of broadly crystalline calcite, globular colloid silica, and silica which is not globular but has a vaguely granular texture and the dull translucency of horn. Close examination shows that this "corneous" silica is distributed irregularly through the slide, occurring throughout, but principally in patches, and in such patches the quartz-grains are fewer in number. With crossed Nicols it is practically neutral, but here and there is a shadowy appearance which seems to be due to an incipient crypto-crystalline structure.

The slide is traversed by one of these irregular patches of silica, and besides scattered quartz grains there are many minute Textularians, the tests of which seem to be still calcitic. Around the borders or outskirts of the area globular silica occurs conspicuously, and it is also possible to see the outlines of globules here and there within the tract of "corneous" silica.

Elsewhere throughout the slide globular silica occurs in profusion between the mineral grains. There are also large broad crystals of calcite, which seem to be thin flattish masses, and are intimately mixed with the rest of the rock. There is, moreover, a curious relation between them and the globular silica, for their edges are everywhere indented with close-set semicircular concavities or excavations. The aspect of these eroded calcite crystals and spicules suggests the idea that the globular silica, at the moment of its formation, had an energetic acid reaction, by which it was able to encroach rapidly upon all the calcareous bodies with which it was in contact, but that after the silica had once taken the globular form no further encroachment or replacement took place.

No. 2. *Part of a small Cowstone from Black Ven* (*see* p. 187).—Seen by transmitted light and under a ⅔ inch objective this rock shows a mass of closely packed mineral grains, chiefly quartz, but with some mica and grains that are probably felspar. Glauconite is present but forms only about 1 per cent. of the coarse material. There are also a few sponge spicules, and a small amount of amorphous inorganic material.

At first sight the chief cementing material appears to be granular crystalline calcite, but closer examination shows that the rock is permeated with the peculiar kind of silica which has been described above. There are several patches or areas of it, where mineral particles are few, though not altogether absent. There is no globular silica in this slide.

No. 3. *Concretion about 20 feet above the Cowstones.*—The ground mass of this consists of granular crystalline calcite embodying a considerable quantity of fine amorphous inorganic matter. The included mineral grains are chiefly quartz, estimated at 40 to 45 per cent. Of glauconite grains there are about 5 per cent. There is no kind of interstitial silica in this slide.

No. 4. *Sandstone between Chert-beds, Hooken Cliff, Beer Head.*—Examined as before with a ⅔ objective this rock is seen to be largely calcareous, the mineral grains (quartz and glauconite) making up but a small portion of its mass. In its original state it appears to have consisted chiefly of definite calcareous particles, such as fragments of shell, with a fair number of Foraminifera, but these are now enveloped and cemented by broadly crystalline calcite. There seems however to have been much finely-divided calcareous matter mixed with the larger particles, and the existence of this has caused a finer and more granular crystallization of the calcite in some

parts of the rock, and this in places interferes with and obscures the definite outlines of the particles.

Quartz occurs in angular and subangular grains; there are a few grains of glauconite, and this mineral fills some of the tests of Foraminifera. No sponge spicules could be seen.

There is also a certain amount of silica present of the same character as that found in No. 2 (Cowstone), two or three patches or *lacunæ* of it being noticed.

No. 5. *Pebble in Sandstone with Exogyra digitata, Whitecliff.*— This was cut because pebbles of sandstone are numerous in this part of the series, and some writers had suggested that they might have been derived from Portlandian Beds.

The slide shows the rock to have been a fine calcareous sand formed of portions of calcareous organisms and finely divided calcareous debris, with about 10 per cent. of angular mineral grains and 1 per cent. of glauconite grains; the whole cemented by crystalline calcite. The individual structure of the calcareous grains, is obliterated by the subsequent crystallization, but these outlines are still quite clear.

The rock is permeated with the same form of horn-coloured silica seen in the Sandstone (No. 4), and in the "Cowstone" (No. 1). Besides minor *lacunæ* there is a very considerable space where this substance occupies the field, enclosing scattered but well-defined grains of quartz and calcareous sand. Its crystallization however is much less obscure in this slide than in the other cases, for with crossed Nicols a fairly-well-marked micro-crystalline structure becomes apparent.

From the above description it is obvious that the pebble has the same structural characters as those of the sandstone which occurs at a lower horizon, at Hooken Cliff, and that it is much more likely to have been derived from the erosion and breaking up of such a bed than from the Portland limestone, no trace of which is known to occur nearer than Portland itself.

CHAPTER XXVI.

SUBTERRANEAN EXTENSION OF THE GAULT AND UPPER GREENSAND.

In the preceding pages we have followed the formation along those tracts where it comes to the surface and is open to the observation of all; but this is only a small portion of the area which is actually occupied by the Selbornian strata and a still smaller portion of the area over which they originally extended. What may be inferred about their former westward extension will be stated in a later chapter; at present we shall concern ourselves with what is known about their extension beneath the newer strata of the London and Hampshire Basins, with a glance at their further extension beneath the great Paris Basin. Such knowledge has of course been obtained from the deep borings which have been made from time to time through the chalk in search either of water or of coal.

1. London Basin and Eastern Counties.

In the Eastern Counties, between the ridge of the North Downs and the northern coast of Norfolk no fewer than seventeen borings have been made, which have traversed the whole or the greater part of the Gault. Of the beds proved by these borings some account will be given, in order to indicate the changes of thickness and of lithic character which the formation exhibits in the area where it is concealed from view.

It will be convenient to commence with the southern part of the London Basin, and to take the most westerly boring first. This is a boring made at New Lodge, Winkfield, about 3½ miles W.S.W. of Windsor Castle, and the following particulars about the Greensand and Gault at this spot are taken from the description published by Mr. Whitaker and myself.[1]

The beds classed as Upper Greensand have a thickness of 31 feet. They were entered at the depth of 939 feet. Specimens down to 943 feet consisted of grey sandy marl full of quartz and glauconite grains. A sample from 956 feet was a calcareous malmstone or "hearthstone"; samples from 960 and 968 were similar, but had less calcareous matter.

Below 970 the rock passed into marl, and stiff, light-grey marls continued to 1,056 feet; below this the material was darker and softer; *Ammonites splendens* occurred at 1,170, and *Inoceramus sulcatus* at 1,170 and 1,179, whence we may conclude that the Upper Gault goes down to 1,180 feet at least. Phosphatic nodules occurred at 1,171 feet.

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[1] Quart. Journ. Geol. Soc. vol. l., p. 488

Lower Gault clays of the usual type were found down to 1,230 feet; then came dark-green and brown sandy clay with a layer of phosphatic nodules at the base, and at 1,235 feet the boring entered fine, sharp, light-brown sand (Lower Greensand).

The above details may be summarised as follows:—

— —		Thickness	Depth.
		Feet.	*Feet.*
Green sandy marls	about	10	949
Hearthstone and firestone	,,	21	970
Upper Gault marls -	,,	210	1,180
Lower Gault clays -	,,	50	1,230
Sandy clay with nodule bed -	,,	4	1,234
		295	

It will be seen that the total thickness amounts to nearly 300 feet. The arenaceous beds are rather thinner than in the Surrey outcrop between Guildford and Reigate, and the argillaceous part is probably thicker, but the general succession is just the same.

Another boring was made at Richmond, about 17 miles east of Windsor, and has been described by Prof. Judd.[1]

From his account we learn that at the depth of 924 feet the boring entered a firestone rock similar to that of Godstone and Merstham. No mention is made of any soft sandy marl above this firestone, probably because no samples of the beds immediately overlying it were examined, for it is not likely that Chalk Marl would rest directly on Firestone. The latter was found to be 16 feet thick and to consist of two beds of hard sandy rock, containing respectively 14·5 and 12·5 of calcium carbonate, and having between them 6 feet of softer marly sandstone, which contains nearly 20 per cent. of the carbonate.

The Gault Marls commenced at 940 feet and yielded the following fossils—*Pentacrinus Fittoni*, *Inoceramus concentricus*, *Hamites armatus* (940 feet), *Ammonites Bouchardianus* (1,059 feet), *Am. rostratus?* (1,062 feet). They may be estimated at probably 150 feet thick, though no certain indication of change from Upper to Lower Gault was observed. A sample from 1,026 feet was found to contain 33 per cent. of calcium carbonate.

The Lower portion of the Gault was dark blue and contained nodules of iron pyrites and of argillaceous ironstone. *Ammonites splendens* occurred at 1,100[2] and 1,128 feet and *Ancyloceras spinigerum* at 1,104 feet. The lowest bed contains much sand, and has a basement layer of phosphatic nodules and small pebbles, resting on a limestone which is probably of lower Cretaceous age

[1] Quart. Journ. Geol. Soc., vol. xl., p. 736.

[2] Dr. J. W. Gregory has pointed out that the Ammonite from 1,100 feet is *Am. splendens*, not *Am. interruptus* as first stated. See Geol. Mag., Dec. 4, vol. ii. p. 101.

The succession may be summarised as follows:—

——		Thickness.	Depth.
		Feet.	*Feet.*
Firestone and Hearthstone	about	16	940
Upper Gault marls -	"	150	1,090
Lower Gault clays - - -	"	50	1,140
Basement Sandy Clay and Nodule Bed	"	1½	1,141½
		217½	—

The next boring to be noticed is that at Meux's Brewery at the southern end of Tottenham Court Road, London. Accounts of this have been published by Sir Joseph Prestwich,[1] and by Mr. Whitaker.[2] From these we learn that the Selbornian was entered at a depth of 812 feet, and that the succession was as follows:—

——	Thickness.	Depth.
	Feet.	*Feet.*
Light grey micaceous sandstones, some soft and some hard (firestone) with green and grey sand below - -	28	840
Bluish grey marly clay with some layers of phosphatic nodules and a hard grey stone bed at 914 feet - - - - ; No description of Lower Gault given -	157	997
Greensand and clay with a layer of phosphatic nodules and pebbles at the base, resting on rocks of Jurassic age - -	3	1,000
	188	—

It will be seen on comparing these three borings that in passing from west to east, the formation overlaps the Lower Greensand on to Jurassic rocks, at the same time losing over 100 feet of thickness, thinning from 295 to 188 feet. The boring at Crossness, near Erith, about 12 miles to the eastward of the last, shows little if any further diminution in that distance, for the thickness of Gault there traversed is stated to be 175 feet, and there may be 10 or 12 feet of green sandy marl above it, but this is uncertain. Here the Gault rests on red rocks of Devonian or Triassic age.

[1] Quart. Journ. Geol. Soc., vol. xxxiv., p. 902 (1878).
[2] The Geology of London. Mem. Geol. Survey, vol. ii., p. 165 (1889).

To the east and north-east this thinning probably continues, but to the south-east the beds thicken towards the outcrop in Kent. Thus borings at and near Chatham have proved the Gault there to be from 192 to 196 feet with Lower Greensand below it.

We may next take a series of borings in a direction north of London. The first of these is one made in 1855 on the road from Kentish Town to Highgate. This appears to have reached Greensand at a depth of 969¼ feet, though no definite base of the Chalk has been recorded. The succession of the beds as given by Prestwich[1] is as follows:—

——	Thickness.		Depth.	
	Feet.	*in.*	*Feet.*	*in.*
Dark green sand mixed with grey clay	13	9	983	0
Bluish grey, slightly sandy, micaceous clay	39	0	1022	0
Do. with two layers of clayey greensand	6	7	1028	7
Micaceous blue clay with a layer of phosphatic nodules at the base	84	11	1113	6
	144	3	—	

The underlying beds are of doubtful age, but some of them may be Triassic. No fossils were actually brought up from the Gault, but *Ammonites rostratus, Am. cristatus,* and several small *Belemnites* (? *minimus*) came up with material from lower beds, and must have fallen down from the sides of the borehole. The small thickness of Gault here is particularly noteworthy.

A boring at Loughton Railway Station, about eleven miles N.E. of Kentish Town, was made in 1874–6, but little information exists concerning it. The Greensand is believed to have been entered at 894 feet and to be 30 feet thick,[2] below this the boring was carried through grey marl and clay to a depth of 1,100 feet, when water was found and the boring stopped. It is fairly certain that the base of the Gault was reached at this depth, and that the thickness of the combined Gault and Greensand is 206 feet, a great increase on the last.

In 1878–9 a boring was made for the New River Company near Cheshunt, which is five miles N.W. of Loughton and about 11 from from Kentish Town. From the latest and most complete account of this the following particulars are taken[3]: the Upper Greensand was entered at a depth of 783 feet and arenaceous beds continued for more than 40 feet. The samples preserved

[1] Quart. Journ. Geol. Soc., vol. xii., p. 6.

[2] According to Mr. Tilley's account. See Geology of London, Mem. Geol. Survey, by W. Whitaker, vol. ii., p. 26.

[3] Quart. Journ. Geol. Soc., vol. l., p. 508.

at the office of the company furnish us with the following succession of beds in descending order:—

Greensand about 44 feet	Grey sandy glauconitic marl -	at 784 feet.
	Soft glauconitic and micaceous sand	„ 790 „
	Hard grey siliceo-calcareous rock	„ 800 „
	Fine grey micaceous sand - -	„ 808 „
	Compact grey calcareous sandstone	„ 850 „
	Fine grey micaceous sand	from 811 to 814 ft.
	Grey sandy limestone, with some glauconite -	at 816 and 818 ft.
	Grey sandy glauconitic marl	„ 819 feet
	Calcareous sandstone, with large grains of glauconite	„ 825 „
Gault about 155 feet	Dark grey silty and somewhat marly clay - - -	„ 836 and 840 ft.
	Clean smooth unctuous clay	„ 844 feet
	Somewhat silty grey clay -	„ 850 „
	Clean homogeneous grey clays -	from 860 to 914 ft
	Hard grey clay with phosphatic nodules and *Inoceramus concentricus* - - -	at 925 feet
	Compact grey clays - - - -	from 928 to 980 ft.
	Dark sand with a layer of phosphatic nodules and broken *Belemnites*	at 981½ feet

The Gault rests directly on Devonian rocks. The total thickness of the formation is 199 feet; there is no indication of the thickness of Lower Gault, but it is probable that all below 925 feet belongs to that division.

Another boring was made about the same time as the last (1877–9) at Ware, which is about 8 miles north of Cheshunt. Of this also the New River Water Company fortunately kept a series of samples which enabled Mr. Whitaker and myself to give a fairly complete account of the beds which were traversed.[1] The Greensand appears to have been reached at a depth of 590 feet, and its thickness is nearly the same as at Cheshunt, *i.e.*, about 40 feet, while the clays below were 166½ feet, making a total of 206½ feet. The succession may be stated as follows:—

	———	Thickness.	Depth.
		Feet.	*Feet.*
Greensand 40 feet.	Soft grey marly sandstone -	23	613
	Fine-grained siliceous rocks resembling malmstone - -	8	621
	Calcareous sandstone and malmstone	9	630
Gault 166½ feet.	Grey silty clays	30	660
	Dark grey marly clays	65	725
	Dark grey compact clays - - -	71	796
	Dark green sand with minute fragments of Palæozoic rocks - - -	0½	796½
		206½	—

The Gault here rests on a limestone of Wenlock age.

[1] See Quart. Journ. Geol Soc., vol. l. p. 501.

A deep boring was made in 1836, at Saffron Walden (Suffolk), about 18 miles N.N.E. of Ware, but no reliable information exists concerning it. It is said to have been carried to a depth of 1,004 feet; the Chalk is said to have been about 500 feet thick; according to Dr. J. Mitchell "the soil appears to have varied but little for the last 700 feet," and the lower part was entirely in blue clay. In the light of subsequent borings to the north, east and south of this place, these statements are so improbable that I can only suppose either that the total depth was greatly overstated, or that with the rude appliances then used, the boring pursued a curved and possibly serpentine course and never really reached the bottom of the Gault, which would probably lie between 600 and 625 feet below Saffron Walden.

Another boring, made at Combs near Stowmarket in 1855, pierced the Chalk at a depth 874 feet and traversed 21 feet of the Selbornian described in one account as Gault and Greensand "alternating," this boring was stopped at 895 feet.

In 1890 a boring was made at Culford Park, near Bury St. Edmunds, and reached the Palæozoic floor at the surprisingly small depth of 637½ feet. The base of the Chalk was not noted by the foreman in charge of the work, and very few samples were kept, but from the available data it is believed that Gault immediately underlies the Chalk Marl and has a thickness of 73 feet, its base being probably at 605 feet. Below this came 32½ feet of grey sand and grey sandy limestone, apparently of Lower Cretaceous age.

From this boring it is evident that the Palæozoic platform continues northward beneath the Gault, and rises to a still higher level. Further it would appear that its western slope is steep and that the Jurassic rocks of Cambridgeshire thin out eastward against it, allowing only thin representatives of the Lower Greensand and of the Gault to pass over the more elevated parts of the surface formed by the Palæozoic rocks.

This surface seems to have been of the nature of a plateau or table-land, or it may have been planed down by the waves as it sank beneath the Gault sea; for other borings further east than those which have been mentioned prove that the Gault clays spread eastward to and beyond the present border of England. Thus, two borings have been made in the extreme north-east of Essex, at Weeley and Harwich; another at Stutton, south of Ipswich, and one at Norwich, all of which proved the existence of Gault beneath the Chalk, and the three former piercing the Gault found Palæozoic rocks underneath. The borings at Stutton and Weeley were made in 1896 and 1897, and no full account of them has yet been published, but samples from both were sent to me for examination by Mr. Whitaker, who will probably publish the full particulars, and meantime assents to my printing such notes as are in my possession.

At Stutton the sample brought up from the depth of 940½ feet has the appearance of being the base of the Chalk, in which case we might expect the Gault would begin at 941 feet, but for the

next three feet the material seems to be a dark green glauconitic marl which may belong to the sub-zone *Stauronema Carteri*, while the sample from 944½ feet is certainly Gault. Admitting the doubt, I shall assume that Gault begins at 944 feet, and as there is a sample of dark grey clay marked 994, the base may be put at 995 feet below which there is hard Palæozoic rock. From samples examined the succession seems to be as follows, but the actual thicknesses of the several parts are uncertain :—

		Thickness. *Feet.*	Depth. *Feet.*
Grey marly clay with glauconite grains and patches of glauconitic sand	about	2	946
Grey marly clay with *Plicatula pectinoides*	,,	4	950
Light grey fine silty marl - - -	,,	15	965
Hard grey marly clay, with patches of glauconitic clay and some phosphatic nodules	,,	5	970
Light grey marly clay - - - -	,,	} 10	980
Compact grey marly clay	,,		
Heavy dark grey clay - - -	,,	15	995
	About	51	

At Weeley, which is about 8 miles south of Stutton, the base of the Chalk occurs between 1,018 and 1,019 feet, and the base of the Gault at about 1,094, so that here there seems to be a greater thickness of Gault, namely, 76 feet.

The boring at Harwich, which lies about 7 miles eastward of Stutton, was made in 1854–7, and described by Prestwich.[1] The beds found between the base of the Chalk and the floor of Palæozoic rocks are stated to have been as follows :—

	Feet.	
Greensand and Gault -	22	} 61
Gault without Greensand	39	

The Gault rested on black slaty rock at the depth of 1,025 feet. By "Greensand and Gault" is, doubtless, meant a set of glauconitic and silty clays like those proved to exist at Stutton, but as the total thickness of Gault comes out 10 feet greater than at the more western locality, it is possible that some of this "greensand and gault" belongs to the glauconitic base of the Chalk Marl.

Of the boring at Norwich various accounts have been given, but the most dependable is that by Mr. W. Whitaker, compiled from a drawing and specimens preserved by Messrs. Colman, on whose premises the boring was made. These showed that the base of Chalk lay not far from and probably at 1,158 feet; below this Gault, probably glauconitic in the upper part, was traversed for 38 feet without reaching the base of it.[2] As

[1] Quart. Journ. Geol. Soc., vol. xiv. p. 250.

[2] Proc. Norwich Geol. Soc., vol. i. p. 250; and H. B. Woodward, Geol. Norwich (Geol. Survey), pp. 7, 163.

the thickness of the Gault at its outcrop west of Norwich is only 60 feet, it is probable that a few feet more of boring would have reached the Palæozoic floor, or possibly the Lower Greensand.

From the accounts given above of the deep borings which have been made in the east of England we learn several important facts. One quite unexpected fact is that true Upper Greensand with characters similar to those of the Malmstones and Firestones of Surrey, Berkshire and Oxfordshire extends northwestward to and presumably some distance beyond Ware. The main outcrop of such rocks does not extend beyond the neighbourhood of Princes Risborough in Bucks, which is about six miles south of the latitude of Ware. To the north and north-east of Ware these arenaceous beds thin out, while the upper part of the Gault becomes silty and glauconitic, so that in the accounts of some borings it has been called "Greensand" or a "mixture of Gault and Greensand."

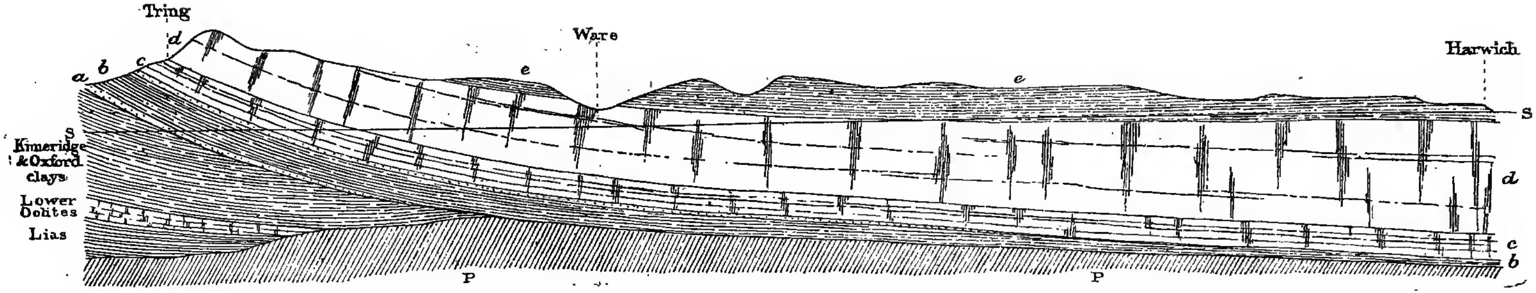
With respect to variations in thickness of the formation as a whole we have seen that between Windsor and London it thins continuously eastward. Similarly on an east and west line through Ware from the outcrop near Tring to Weeley and Harwich in the east of Essex there is also a great diminution of thickness, from 230 feet near Tring to 206 at Ware, and finally to between 50 and 60 at Harwich. Fig. 83 is a section along this line to show this easterly thinning as well as the manner in which the Jurassic strata are supposed to thin out against the western slope of the old Palæozoic land, and the surface of erosion formed by the waves of the Gault sea across the Jurassic and the Palæozoic rocks as the ancient land surface sank beneath them.

It is evident from this section that if the rate of thinning were continued as between Ware and Harwich, a distance of about 60 miles, the Gault would thin out entirely in another 20 miles beneath the North Sea. Whether it actually does so we have no means of knowing at present, but a boring at Ostend, in Belgium, proved that the chalk there rested directly on the Palæozoic rocks, so that it is certain the Gault does thin out somewhere to the east of England, and is overlapped by the Chalk.

Turning next to the evidence of change in a northerly direction we find the thicknesses are more irregular. From a thickness of 188 feet under London (Oxford Street) the formation thins rapidly to 144 feet at Kentish Town, and then increases to 206 feet at Loughton, between which place and Ware the thickness does not seem to vary much. These facts suggest the inference that this portion of the sea-floor rose into an east and west ridge below Kentish Town, that the Jurassic rocks thinned out against the southern border of the ridge, and that though it sank beneath the sea of the Gault, less of that material was deposited on the ridge than in the presumably deeper water to the north of it.

Between Ware and Culford we have at present no evidence, but in this distance of 47 miles the Gault diminishes from 206 to about 73 feet, and the floor on which it rests comes up to within 638 feet of the surface. There is, however, no reason to

FIG. 83. *Diagram-section from Tring to Harwich.*



Horizontal Scale 12 miles to an inch.

e. Pleistocene and Tertiary Deposits.
d. Upper and Middle Chalk.
c. Lower Chalk.
b. Gault and Upper Greensand.

Vertical Scale 1,600 feet to an inch.

a. Lower Greensand.
P. P. Palæozoic Rocks.
s. s. Sea Level.

suppose that this is due to a local and abnormal rise of the floor, since a similar thinning takes place along the outcrop. The rise of the floor is probably concomitant with the rise of the Cretaceous and Tertiary Beds from the syncline of the London Basin.

2. Hampshire Basin.

This is a much smaller area than the London Basin, but is also a much deeper trough, and very few borings within its limits have been carried deep enough to reach the Gault. The only one which has passed completely through it is that at Rottingdean, near Brighton.

There is, however, no reason to doubt that the Gault and Upper Greensand are perfectly continuous beneath the whole of the basin from West Dorset to Sussex, and from the Isle of Wight to the inlying tracts of Shalbourn and Kingsclere in the north. It will be useful, however, to point out some of the changes that must take place as the beds pass southward and westward.

We have already mentioned the change that takes place in the northern part of the basin as the beds are traced from the neighbourhood of Farnham through Kingsclere to the Vale of Pewsey (see pages 93 and 113). In passing beneath the eastern part of the basin, from near Petersfield to the eastern end of the Isle of Wight, there is less change; the succession near Petersfield of greenish sand, malmstone, sandy marl and gault clay is not unlike that of greensand, grey marly sandstone, sandy clay and gault between Culver and Redcliffe.

In respect of thickness the chief point to be noticed is the great diminution which takes place beneath the whole basin from west to east. Thus between Selborne and Shaftesbury, a distance of about 53 miles, the formation as a whole thins from about 280 to 150 feet, a loss of 130 feet. Taking the line of the south coast from Brighton to Ringstead Bay we find it thins from 312 feet to about 165 feet, showing a loss of 147. The irregularities of thickness in the Isle of Wight and in Dorset, however, show us that we must not assume that this diminution is gradual and continuous. There are, in fact, two points of local attenuation along this line, one is in Compton Bay (Isle of Wight), the other is at Man of War Cove, Dorset; and, curiously enough, the estimated thickness of the combined Gault and Greensand is just the same, namely, 132 feet. The variations along this line, so far as we at present know them, are consequently as follows:—

Ringstead.	Man of War Cove.	Warbarrow.	Swanage.	Compton Bay.	Culver.	Brighton.
165	132	167	156	132	198	312

The variations in the relative thickness of the argillaceous and arenaceous parts of the formation are of comparatively little importance, beyond the fact that the clays of the eastern part of the region are gradually replaced by silts and sands in the western part.

The Chalk of the Hampshire Basin extends south-eastward beneath the English Channel to the coast of France, between Dieppe and Boulogne. It is believed that the anticlinal axis of the Pays de Bray in France, is part of the same line of flexure as that which traverses the Isle of Wight, and it is probable that from the eastern end of the Wight the submarine outcrop of the Selbornian sands and clays passes in a south-easterly direction towards Dieppe, and then curves southward to Fécamp, where it is faulted down to the west, but rises again to the shore at St. Jouin near Havre. A recent boring at Dieppe has proved the base of the Chalk, to be there 519 feet from the surface, and about 489 feet below the level of the sea. The particulars of this boring are given on p. 398.

CHAPTER XXVII.

GAULT AND UPPER GREENSAND IN NORTHERN FRANCE.

1. Eastern Border of the Paris Basin.

Boulonnais and Pas de Calais.—In crossing the Channel from Folkestone to Wissant the Gault thins from over 100 feet to only 42 feet, but in this smaller thickness a similar succession of beds is exhibited. It is divisible into Lower and Upper Gault, but the idea of detaching the Upper Gault from the Albian and attaching it to the Cenomanian seems to us contrary both to stratigraphical and palæontological evidence. The following description is taken from Dr. Barrois' papers.[1] Arranged in descending order the section is briefly this:—

	Feet.	in.
3. Grey marly clay, with *Inoceramus sulcatus*, *Ammonites rostratus*, and other fossils	23	4
2. Darkish blue-grey clay, with *Am. auritus*, *Am interruptus*, &c., and a layer of phosphatic nodules and lumps of pyrites at the base	16	8
1. Quartz sand with green grains, sometimes a sandstone; *Am. mammillatus*, *Inoc. Salomoni*, and many phosphatic nodules and casts	2	0
	42	0

No. 1 is clearly the equivalent of the sand with *Am. mammillatus* at Folkestone. No. 2 represents the beds which Mr. Price numbered as I. to VII.; it is not likely that so many horizons could be distinguished at Wissant, but the range of the fossils in this subdivision has not yet been ascertained. These two beds, 1 and 2, form the Lower Gault, and No. 3 is the Upper Gault. The following is a list of the fossils which have been obtained from each division by Dr. Barrois and Mr. F. G. H. Price.[2]

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[1] Sur le Gault dans le bassin de Paris, Ann. Soc. Geol. Nord, T. ii., p. 1 (1875); Terrain Crétacé des Ardennes; Op. Cit., T. v., p. 227 (1878), and Proc. Geol. Assoc., Vol. vi., p. 27 (1879).

[2] Mr. Price sent J. Griffiths of Folkestone to collect from the Gault of Wissant for him in 1878, and his list from the Upper Gault is the only one yet published.

LIST OF FOSSILS FROM THE GAULT OF WISSANT.

——	Zone of Am. mammillatus.	Zone of Am. interruptus.	Zone of Am. rostratus.
Pisces.			
Chimæra Bouchardi, *Sauv.*	x	–	–
Lamna appendiculata, *Ag.*	x	x	x
„ Bouchardi, *Sauv.*	–	?	–
„ macrorhiza, *Cope*	–	?	–
„ subinflata, *Ag.*	–	x	x
Scapanorhyncus raphiodon, *Ag.*	x	–	–
Sphenodus	–	–	x
Cephalopoda.			
Belemnites attenuatus, *Sow.*	x	–	–
„ minimus, *List.*	x	–	x
Nautilus bouchardianus, *d'Orb.*	x	–	–
„ clementinus, *d'Orb.*	x	x	x
Ammonites auritus, *Sow.*	–	x	x
„ Beudanti, *Brong.*	x	–	–
„ cœlonotus, *Seeley*	–	x	–
„ cristatus, *de Luc*	–	–	x
„ Delaruei, *d'Orb.*	–	x	x
„ denarius, *Sow.*		x	–
„ fissicostatus, *d'Orb.*	x	–	–
„ interruptus, *Brug.*	x	x	–
„ latidorsatus, *Mich.*	–	x	x
„ lautus, *Sow.*	–	x	x
„ mammillatus, *Schloth*	x	–	–
„ Mantelli, *Sow.*	–	–	x
„ raulinianus, *d'Orb.*	x	x	
„ rostratus, *Sow.*	–	–	x
„ splendens, *Sow.*	–	x	x
„ tuberculatus, *Sow.*	–	x	x
„ varicosus, *Sow.*	–	–	x
Ancyloceras spiniger, *Sow.*	–	x	x
Hamites attenuatus, *Sow.*	x	x	?
„ bouchardianus, *d'Orb.*	x	–	–
„ elegans, *d'Orb.*		x	x
„ flexuosus, *d'Orb.*	–	x	x
„ intermedius, *Sow.*	–	–	x
„ virgulatus, *d'Orb.*	–	–	x
Gasteropoda.			
Actæon vibrayeana, *d'Orb.*	–	x	
Aporrhais carinata, *Mant.*	–	x	–
„ costata, *Mich.*	–	x	–
„ elongata, *Sow.*	–	x	
„ Parkinsoni, *Mant.*	x	x	x
„ retusa, *Sow.*	x	–	–
Avellana inflata, *d'Orb.*	x	–	–
Bellerophina minuta, *Sow.*	–	x	–
Buccinum gaultinum, *d'Orb.*	x	–	–

List of Fossils from the Gault of Wissant—*cont.*

——	Zone of Am. mammillatus.	Zone of Am. interruptus.	Zone of Am. rostratus.
Gasteropoda—cont.			
Cerithium ornatissimum, *Desh.*	x	–	–
„ trimonile, *Mich.* -		x	–
Dentalium decussatum, *Sow.*	x	x	x
Fusus Smithii, *Sow.* - - -	–	x	–
Natica gaultina, *d'Orb.* (= N. Genti)	x	x	–
„ clementina, *d'Orb.*	–	x	–
„ excavata, *Mich.*	–	x	–
Pleurotomaria gaultina, *d'Orb.*	–	x	
Scalaria dupiniana, *d'Orb.*	x	x	x
„ gaultina, *d'Orb.* -	–	x	–
Solarium cirrhoide, *d'Orb.*	–	x	
„ dentatum, *d'Orb* -	–	x	x
„ moniliferum, *Mich.*	–	x	–
„ ornatum, *Sow.*	–	x	–
Trochus conoideus, *Sow.* (= Solarium) - - -	–	x	x
Lamellibranchiata.			
Arca (Cucullæa) carinata, *Sow.*	x	x	x
„ „ glabra, *Park.*	x	x	x
Cardita Constanti, *d'Orb.*	x	–	
„ tenuicosta, *Sow.*	–	x	x
Corbula elegans, *Sow.* -	–	x	x
„ socialis, *d'Orb.*	–	x	x
Crassatella inornata, *d'Orb.* -	–	x	–
Cyprina cordiformis, *d'Orb.* - -	x	–	–
„ ervyensis, *d'Orb.*	x	–	–
„ regularis, *d'Orb.* -	x	–	–
Inoceramus concentricus, *Park.* -	x	x	x
„ Salomoni, *d'Orb.* -	x		–
„ sulcatus, *Park.* - -	–	–	x
Leda Mariæ, *d'Orb.* -	–	x	–
„ solea, *d'Orb.*	–	x	–
„ subrecurva, *Phil.*	–	x	–
„ vibrayeana, *d'Orb.* - -		x	–
Lima parellela, *d'Orb.* (non *Sow.*)		x	x
Mytilus Cuvieri, *Math.* - -	x	–	–
Nucula albensis, *d'Orb.* -	–	x	–
„ bivirgata, *Sow.* -	–	x	–
„ capsæformis, *Mich.* -	–	x	–
„ ovata, *Mant.* -	x	x	x
„ ornatissima, *d'Orb.* -	–	x	–
„ pectinata, *Sow.*	x	x	x
Ostrea arduennensis, *d'Orb.* -	x	–	x
Pleuromya plicata, *Sow.* - -	x	–	–
Pecten orbicularis, *Sow.*	x	–	–
„ raulinianus, *d'Orb.*	–	–	x
Plicatula radiola, *Lam.* - -	x	–	–
„ pectinoides, *Sow.* -		x	x
Teredo argonnensis, *Buv.*	x	–	–

List of Fossils from the Gault of Wissant—*cont.*

——	Zone of Am. mammillatus.	Zone of Am. interruptus.	Zone of Am. rostratus.
Lamellibranchiata—cont.			
Teredo sp.	–	–	x
Thetis Sowerbyi, *Röm.*	x	–	–
Thracia simplex, *d'Orb.*	–	x	–
Trigonia caudata, *Ag.*	x	–	
„ Fittoni, *Desh.*	x	–	–
Venus vibrayeana, *d'Orb.*	x	–	–
Brachiopoda.			
Rhynchonella gibbsiana, *Sow.*	x	–	–
„ cantabrigensis, *Dav.*	x	–	
Terebratula biplicata, *Sow.*	x	–	–
„ moutoniana, *d'Orb.*	–	–	x
Echinodermata, &c.			
Cidaris gaultina, *Forbes*			x
Hemiaster asterias, *Forbes*	–	x	–
Serpula articulata, *Sow.*		–	x
Crustacea.			
Necrocarcinus Bechei, *Desl.*	–	x	–
Palæocorystes Broderipi, *Mant.*	–	x	–
„ Stokesi, *Mant.*	–	x	
Actinozoa.			
Ceratotrochus insignis, *Dunc.*	–	x	–
Trochocyathus harveyanus, *M. Ed.*	–	x	–

From Wissant the Gault can be traced all along the eastern border of the Boulonnais, but becomes still thinner toward the south. At Caffiers the zone of *Ammonites mammillatus* rests directly on the upturned Devonian rocks of the axis of Artois, as shown in the section drawn by the late W. Topley,[1] and

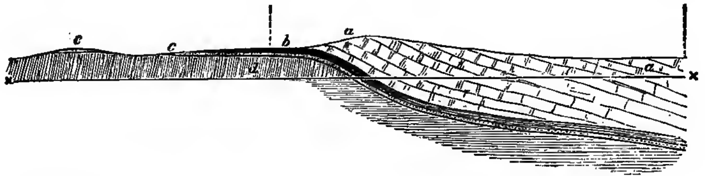
[1] Quart. Journ. Geol. Soc., Vol. xxiv. (1868), p. 474.

reproduced below (Fig. 84). Mr. Topley observed the following succession in the railway cutting near Caffiers:—

		Feet.	in.
Zone of Am. interruptus.	Blue clay, more than - - -	5	0
	Layer of phosphatic nodules and fossils	1	0
	Very green sand -	2	0
	Layer of phosphatic nodules	0	1
Zone of Am. mammillatus	Greenish rather clayey sand - -	2	0
	Light greenish and grey sand, reddish below	3	0
	Lignite, not constant - - - - - -	0	2
	Greenish sand, resting unconformably on	2	0
	Highly inclined shales (Devonian).		

In the cutting at Wierre au Bois, on the line from Boulogne to St. Omer, the Gault is seen again, and is described by Dr. Barrois as a black clay about 23 feet thick, and containing many fossils. Below this is a dark green glauconitic sand with a layer of phosphatic nodules at the base containing *Am. interruptus* and some other fossils; the thickness of this sand is about 18 inches,[1] and it is referred to the zone of *Am. mammillatus*, though Dr. Barrois does not mention the occurrence of that species.

Fig. 84. *Section through Caffiers, Bas-Boulonnais.* (W. Topley.)



a. Chalk.
b. Albian clays (Gault).
c. Albian sands.
d. Palæozoic rocks.
× × Sea level.

The Axis of Artois.—The ridge of Palæozoic rocks which is known as the axis of Artois was dry land during the formation of the French Neocomian and Aptien (our Wealden and Vectian); but the subsidence which carried the Gault over the Palæozoic plateau of eastern England submerged also a part of the Artois highland. It was not, however, so deeply submerged, and throughout the period with which we are now concerned it must have formed a tract of shallow water dividing the deeper water of the Belgian Sea from the still greater depths of the Paris basin.

Where the Palæozoic rocks come near the present surface in Artois, the only representatives of our Gault and Greensand are a variable set of sands, generally only a few feet thick, and evidently formed in shallow water. They rest upon the upturned edges of the Devonian and Carboniferous rocks, and are among the deposits which the miners and quarrymen call "*Tourtia.*"[2]

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[1] Ann. Soc. des Sciences de Lille (1873), Vol. xi.

[2] This is a miner's term given to the loose irregular deposits which cover the surface of the older rocks, and it includes beds of various ages, both Albian and Cenomanian.

If we pass from the south-east corner of the Boulonnais over the Chalk Downs, we find the base of the Upper Cretaceous series exposed again in the valley of the Lys, north of Fruges Along this valley, and in the country to the eastward, many, pits have been opened for the purpose of extracting the phosphatic nodules from the "Tourtias," and the fossils from these beds have been diligently collected by M. Parent, who published an account of them in 1893.[1]

M. Parent distinguishes three distinct faunas in the basement beds of different localities in going from west to east—namely, (1) the Sables verts de Dennebrœucq, (2) the Tourtia de Pernes (3) the Tourtia d'Aix-en-Gohelle. The first he refers to the highest part of the Aptian, the second to the Albian (or Lower Gault), and the third he is inclined to regard as representing the zone of *Ammonites inflatus* (= *rostratus*).

He may be right with regard to Nos. 2 and 3, but we cannot agree with his reference of the greensand of Dennebrœucq to the Aptian. Most of the species which he quotes as belonging to the "English Lower Greensand" are really Blackdown species, and the whole fauna has very strong Gault affinities, as he himself admits. The only Ammonite he found is *Am. tardefurcatus*, a characteristic Albian species which does not occur below the zone of *Am. mammillatus*.

Regarded collectively the fauna of these basement beds is a littoral one, characterised by the rarity of Ammonites and by the abundance of Oysters, Pectens, and Brachiopods. With such a fauna it is hardly possible to make zonal correlations, and it is a significant fact that in every section the basement *Tourtia* is overlain by a glauconitic sand which he calls the "assise à Pecten asper," without any signs of erosion except at Aix-en-Gohelle. We should regard the sands of Dennebrœucq and the Tourtia of Pernes as littoral deposits representing our Lower Gault; and it is quite possible that they were originally succeeded by beds of Upper Gault age, for M. Parent finds derived phosphatic fossils in the sands with *P. asper* at Pernes which seem to have come from such beds. As the zone of *Am. inflatus* certainly had a wider extension than the Lower Gault, one would have expected to find it in Artois, and this supposition of its former existence and subsequent destruction by erosive currents will explain its absence.

Dr. Barrois and Prof. Gosselet have also recorded *Am. inflatus*, *Am. splendens* and *Inoceramus sulcatus* from borings near Douai, and their occurrence seems to confirm the view that deposits of this age were formed, and perhaps still exist, beneath the Chalk of that district.

With respect to the beds referred by M. Parent to the "assise à *Pecten asper*," the fauna certainly has a very close resemblance to that which is generally known as the Warminster fauna,

[1] Ann. Soc. Géol. Nord., vol. xxi., p. 205.

and is found in the sand which immediately underlies the Chloritic Marl near that place. The probability of this correlation is increased by the fact that the "assise à *P. asper*" is overlain by a bed which contains many species of Cephalopoda, and appears to correspond with our Chloritic Marl.

We do not propose to describe the Tourtias and deposits which occur further east in the Department du Nord, and will only remark that there appear to be in that region sporadic deposits, some referable to the zone of *Am. mammillatus*, and others like the "sarrazin de Bellignies," which are of later date. In the direction of Mons, however, there appears to have been an inlet or bay wherein a thick deposit of sand and sandstone was formed, having a strong resemblance to our Blackdown beds. These sands are in places over 300 feet thick, and are known as the Meule de Bracquegnies; they contain layers and concretions of chalcedonic silica, and the fossils are silicified like those of Blackdown. A large number of species are common to the two formations, and there can be little doubt that they are of the same age. In this opinion we agree with Prof. Gosselet and Prof. Barrois, but it is a curious fact that no Ammonites or other Cephalopoda have yet been found in the Meule de Bracquegnies.

The Aisne and Ardennes.—The Gault which passes beneath the chalk on the southern border of the Boulonnais is doubtless continued beneath the southern part of the department (Pas de Calais), and along the northern border of the Aisne, but it does not crop out again from beneath the overlapping chalk till we come to Mondrepuits and Hirson in the north-east of Aisne. From this point the outcrop can be followed southward through the Departments of Aisne, Ardennes, Marne, Haute-Marne, Aube and Yonne.

In the Aisne and Ardennes the beds which correspond to our Gault and Greensand vary much both in lithological character and in thickness, and for our knowledge of these variations we are indebted chiefly to the explorations of Prof. Barrois. For the names of the geologists who preceded him in this field of research we may refer to the full Bibliography given by him.[1]

Taking the zones in ascending order and commencing with the northern district of Thiérache, we learn that the zone of *Ammonites mammillatus* is there represented by the Sables de Liart, which are coarse yellowish sands with large grains of glauconite, and include layers of argillaceous sand containing lumps of hard, coarse glauconitic sandstone. These sands are about 60 feet thick. Southward the sands become finer, and near Maranwez they pass into fine sand with layers of soft sandstone, and many scattered phosphatic nodules.

In the Rethelois this sand becomes a gaize, light and porous, which has been named the Gaize de Draize by Prof. Barrois to distinguish it from the Gaize de Marlemont which overlies it. It

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[1] "Terrain Crétacé des Ardennes," Ann. Soc. Géol. Nord, Tom. v., p. 227 (1878), and "Le Gault dans le Bassin de Paris," Idem, Tom. ii., p. 1 (1875), and Bull. Soc. Géol. de France, Sér. 3., Tom. iii., p. 707.

is well exposed at Rocquigny and Draize, and its thickness is from 30 to 40 feet. Further south, however, between Rocquigny and Attigny (near Rethel), this zone seems to have suffered erosion, for it is represented by a few feet of green argillaceous sand, the surface of which is uneven and covered by a layer of derived phosphatic nodules and fossils; and the sand itself rests on the Coral Rag.

The clays of the Gault (zone of *Ammonites interruptus*) are but poorly represented in Ardennes. Dr. Barrois believes them to be absent, but he describes the Sables de Liart at Buire and Foigny as overlain by a black marl which contains a curious mixture of Lower and Upper Gault fossils, such as *Am. interruptus* and *Am. selliguinus* with *Am. Studeri* and *Inoceramus sulcatus.* Further south there is certainly no trace of the "Middle Gault," and there is evidence of erosion and discordance between the lower and upper portions of the formation at Marlemont and other places.

The zone of *Ammonites rostratus* is represented in the north of Thiérache by sandy clay, which when traced southward passes into fine grey argillaceous sand with cherty nodules and layers of micaceous sandstone. This passes into the Gaize de Marlemont, a fine grey porous sandstone with much colloid silica, which has a maximum thickness of about 50 feet, and a fauna similar to the malmstone of Hampshire and the Gaize of Devizes. It is interesting to notice the occurrence of *Ammonites auritus, var. catillus*, Sow., and of a variety intermediate between *A. auritus* and *A. renauxianus*, also of such species as *Pleuromya mandibula, Arca (Cucullœa) carinata* and *Pinna tetragona.*

This gaize dies out southward, and in the district north of Rethel only a few metres of sandy clay represent the Upper Gault. The following sections are illustrative of the three aspects of the formation along its outcrop between Hirson and Rethel.

The first is at Rumigny, in the Thiérache, and is as follows:—

		Feet.
	Glauconitic Marl with *Pecten asper* -	—
Zone of Am. rostratus.	Green clay sand, *Nucula obtusa* - - - - -	16
	Green clayey sand with thin beds of gaize, and nodules of hardstone: *Amm. Renauxianus Inoc. sulcatus*, &c. - - - - - -	33
Zone of Am. mammillatus.	Ferruginous sand with lumps of coarse grit and thin layers bluish sandstone rich in fossils, *Pleuromya acutisulcata*, &c. - -	50
	Clayey glauconitic sand with lumps of coarse sandstone, *Ostrea arduennensis* -	16
	Aptian below.	115

The sections near Marlemont show:—

	Feet
Marne de Givron with *Pecten asper* - - - -	30
Fine green sand with beds of soft lustrous light grey siliceous stone (*Gaize de Marlemont*) - about	50
Coarse sands with large grains of glauconite, *Sables de Liart* - - - - - - - - about	40
	90

Lastly, near Faux, Rethel and Sorcy, the succession is as below :—

	Feet.
Marne de Givron, grey glauconitic marl -	20 to 30
Zone of Am. inflatus, black sandy clay -	10 to 13
Zone of Am mammillatus, clayey green sand -	8 to 10

The last is the region of least thickness where the combined zones of *Am. mammillatus* and *Am. inflatus* amount to only about 20 feet, and where the former rests on the Corallian limestones which seem to have formed a submarine ridge; the thickness of deposit being less on this ridge than in the deeper water to the north and south of it.

The Marne de Givron, which overlies the zone of *Ammonites inflatus* in this district, is referred by Dr. Barrois to his zone of *Pecten asper*, which in 1878 he restricted to the beds which lie below the niveau of *Am. laticlavius.* If this niveau in the Ardennes and the Aisne is really the equivalent of the basal bed of the Chalk at Wissant and Folkestone, then the Marne de Givron must represent the higher part of our Upper Greensand. We do not think, however, that Dr. Barrois has established the identity of the bed which he calls the zone of *Am. laticlavius* in these departments, and consequently we doubt if the Marne de Givron comes within the series which represents our Gault and Upper Greensand in the east of France. The matter will be discussed more fully when we describe the equivalents of our Lower Chalk in that region.

The Region of Argonne.—South of Rethel we come to the region of Argonne which includes part of the Ardennes with the adjoining parts of Marne and Meuse; and in this district the beds attain a wonderful development.

The zone of *Am. mammillatus* varies from 16 to 30 feet in thickness, but has suffered erosion, for at many places its surface is irregular and supports a layer of phosphatic nodules which are locally known as the "coquins de sable" and are overlain by the Gault clays.

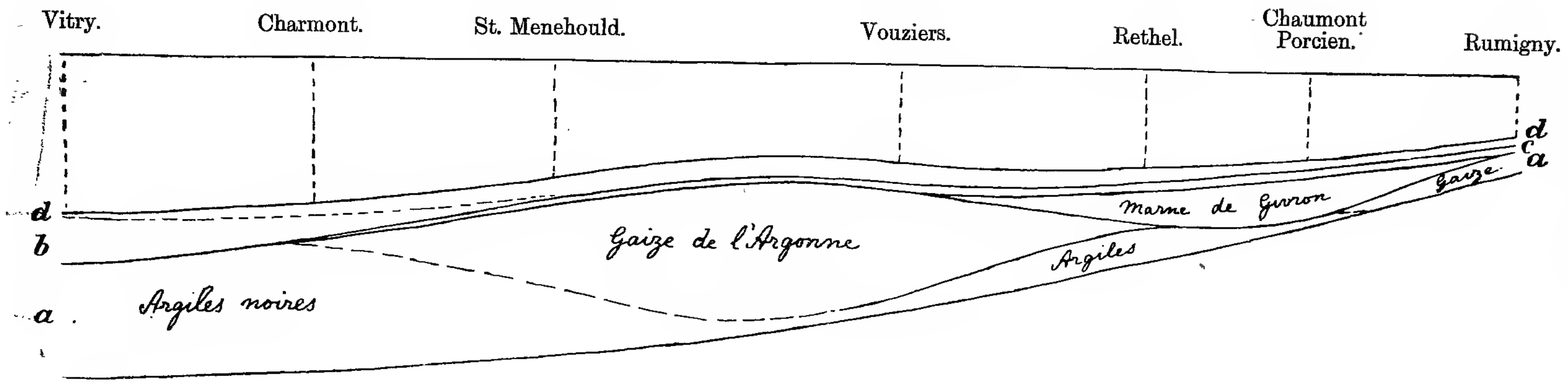
The zone of *Am. interruptus,* which is absent to the north, here sets in again, and is about 30 feet thick near Grand Pré, increasing to 50 feet by Varennes and Clermont.

It is however the zone of *Ammonites inflatus* which attains such a great expansion and this consists largely of gaize. The "gaize de l'Argonne" sets in at Attigny and rapidly thickens till at Grand Pré and Vouziers it is 250 feet, and near Montblainville no less than 330 feet. Southwards it thins again, but as it does so, clays with *Am. inflatus* come in at its base, and evidently replace it, for they thicken as the gaize thins, and when the gaize disappears near Bettancourt these Upper Gault clays are 250 feet thick.

In England the gaize would have been mapped as Upper Greensand and the clays as "Gault," but in France they have long been recognised as only different facies of one formation, the "assise" of *Ammonites inflatus.* As Prof. Barrois remarks, "The end of the gaize at Bettancourt is not the extremity of a special formation having a fauna of its own and ending in

FIG. 85.—*Diagram-section of Gault and Gaize in Argonne.*

Horizontal scale about 20 miles to an inch.



a. Zone of Ammonites inflatus.
b. Zone of Ammonites rotomagensis.
c. "Sables de la Hardoye" and Glauconitic Marl.
d. Zone of Actinocamax plenus.

a feather-edge; it is the border of a lenticular mass *(lentille)* of arenaceous material forming part of an argillaceous formation and having the fauna of that formation."[1]

A peculiarity of the Gaize de l'Argonne is that it contains a layer of phosphatic nodules. Between Grand Pré and Montblainville this layer is from 30 to 50 feet above its base, but sometimes it is at the base. The nodules are known by the workmen as *coquins riches,* because they contain a larger amount of phosphate than the *coquins de sable* of the lower beds; they are black, like those of Cambridge, rolled, worn, and covered with small shells and *Serpulæ,* so that Dr. Barrois regards them as derived either from the lower part of the gaize or from clays which have been destroyed.

It seems to us that further investigation is needed here, for we are not told whether the gaize below contains fossils, or whether this bed of nodules passes into the clays where the gaize is replaced by them southwards, as it should do if it keeps to one stratigraphical horizon.

Marne and Haute-Marne.—Beyond the district of Argonne the succession remains nearly constant, all the three zones being present, and the two higher of these subdivisions maintaining a great thickness, as given below:—

	Feet.
Marly clays of the zone of *Am. inflatus* -	300 to 330
Clays of the Lower Gault	100 to 130
Sands of the *Am. mammillatus* zone -	25 to 30

The total thickness varying from 430–480 feet.

Department of the Aube.—In this department the outcrop of the Gault clays occupies so wide a tract of country that many brickyards have been opened in it, and from these excavations large numbers of fine fossils have been obtained. It was from this region that d'Orbigny obtained his Gault fossils, and on this account he gave the name of *Albien* to the stage that could be recognised by this fauna.

The general succession is much the same as that of the Marne. The grey marly clays of the Upper Gault continue to be from 230 to 250 feet thick; the clays of the Lower Gault (zone of *Am. interruptus*) are over 100 feet, and include at Gaty a layer of small septarian nodules from which many fossils have been obtained. At the base are the sands of the *Am. mammillatus* zone, or, as they used to to be called, the "sables verts inférieurs," from 20 to 30 feet thick.

The Gault of Brienne has been specially studied by M. Delatour,[2] who has recognised a certain subzonal distribution of the fossils. The succession given by him is as follows, and applies to the whole district of the Perthois lying between the Seine and the Ornain rivers:—

Upper Gault.	Zone à Am. rostratus -	230 feet.
	„ à Kingena lima and Pecten raulinianus -	
	„ à Am. varicosus and Inoceramus sulcatus -	
	Ferruginous conglomerate	2 „

[1] Ann. Soc. Géol. Nord, vol. ii., p. 24 (1875).

[2] Bull. Soc. Géol. de France, Sér. 3, tome. v., p. 22, revised in Price's "Lecture on the Gault," 1879, p. 38 (Taylor and Francis).

Lower Gault.	Zone à Am. splendens	about	50 feet
	„ à Am. interruptus	„	65 „
	„ à Crustacea		
	„ à Hamites rotundus		50 „
	„ à Belemnites minimus		
	Sands of the A. mammillatus zone without fossils		30 „

Mr. Price has kindly allowed us to see the letters and lists communicated to him by M. Delatour, and from them we have gleaned the following facts.

The lowest part of the Gault clay is characterised by the abundance of *Belemnites minimus*, which does not range above it. It is divisible into three parts, which seem equivalent to the beds 1, 2, 3 of Mr. Price at Folkestone. No. 1 is divided from 2 by a layer of phosphatic nodules with rolled fragments of *Am. denarius*, *Am. mammillatus*, *Dentalium decussatum* and *Ostrea canaliculata*, but none of these beds contain *Am. interruptus.* The thicknesses of the several beds are not given.

In the clays above, *Am. interruptus* is common, together with *Am. denarius* and *Am. Beudanti* and many other well-known species. He cannot, however, separate this into sub-zones, but regards the whole as corresponding with beds 4. 5 and 6 of Price's Folkestone section.

His zone of *Am. splendens* might have been named the zone of *Am. auritus*, since that fossil is particularly common and does not occur below. It is clearly equivalent to Mr. Price's Bed 7, in which *auritus* is equally common. M. Delatour, moreover, has found in it *Epiaster ricordeanus*, and believes it to be the continuation of the zone of *Ep. ricordeanus* which overlies the sables de Frécambault at St. Florentin, and he has traced it northwards to Montierender in the Haute Marne, where it is overlain by a bed of ferruginous conglomerate. This is important, as Dr. Barrois had not been able to trace the zone of *Ep. ricordeanus* into the Haute Marne.

Above the conglomerate there is marly clay with *Ammonites varicosus* and *Inoceramus sulcatus*, the latter in great abundance; this has its counterpart in Mr. Price's Bed 9 of Folkestone. Its outcrop passes through the town of Brienne, where M. Delatour found two hard beds of marly limestone, the lower one crowded with *Am. varicosus* and *Inoc. sulcatus*, while in the upper band he found a large keeled Ammonite which may be *Am. rostratus.* The total thickness of the zone was not ascertained.

Above this come beds in which *Pecten raulinianus* and *Kingena lima* are common, just as at Folkestone (Bed 10), and lastly a great thickness of marly clays, in which fossils are rare, except *Ostrea canaliculata*, but from which Dr. Barrois obtained *Am. rostratus* at Larrivour and Venizy.

The marls above the conglomerate are ranked by M. Delatour as "Argiles Cenomaniennes," but that is only because the "assise à *Am. inflatus*" is at the present time excluded from the Albien in France; they are none the less absolutely synchronous with our Upper Gault.

The following is a zonal list of the fossils found in the Lower Gault of the Perthois district by M. Delatour:—

———	I.	II.	III.	IV. V. VI.	VII.
CEPHALOPODA.					
Ammonites auritus, *Sow.*	–	–	–	–	x
" Archiacinus, *d'Orb.*	–	–	–	x	–
" Beudanti, *Brong.*	–	x	x	x	–
" bouchardianus, *d'Orb.*	–	–	x	–	–
" Delaruei, *dOrb.*	–	–	x	–	–
" denarius, *Sow.*	x	x	x	x	x
" Deshayesi, *Leym.*	–	–	–	x	–
" dupinianus, *d'Orb.*	–	–	x	–	–
" itierianus, *d'Orb.*	–	–	–	x	–
" interruptus, *Brug.*	–	–	–	x	–
" latidorsatus, *Mich.*	–	x	x	x	–
" Lyelli, *Leym.*	–	–	–	x	–
" mammillatus, *Schloth.*	x	x	x	x	–
" roissyanus, *d'Orb.*	–	–	–	x	–
" splendens, *Sow.*	–	–	–	–	x
" versicostatus, *Mich.*	–	–	–	x	–
Hamites alternatus, *Mant.*	–	–	–	x	–
" bouchardianus, *d'Orb.*	–	–	–	x	–
" rotundus, *Sow.*	–	x	–	–	–
Turrilites catenatus, *d'Orb.*	–	–	–	–	x
Belemnites minimus, *Lister*	x	x	x	–	–
GASTEROPODA.					
Aporrhais carinata, *Sow.*	–	–	–	x	–
Cerithium subspinosum, *Desh.*	–	–	–	x	–
" trimonile, *Mich.*	–	–	–	x	–
Dentalium decussatum, *Sow.*	–	x	x	x	x
Natica gaultina, *d'Orb.*	–	–	–	x	–
Rissoina Sowerbyi, *Gard.*	–	–	–	x	–
Solarium conoideum, *Sow.*	–	–	–	x	–
" ornatum, *Sow.*	–	–	–	–	x
Turritella vibrayeana, *d'Orb.*	–	–	–	x	–
LAMELLIBRANCHIATA.					
Arca (Cucullæa) nana, *d'Orb.*	–	–	–	x	–
" " glabra, *Park.*	–	–	–	?	–
Anomia	–	–	–	–	x
Cardita tenuicosta, *Sow.*	–	–	–	x	x
Inoceramus concentricus, *Park.*	x	x	x	x	x
Lima parallela, *d'Orb.* (non *Sow.*)	–	–	–	x	x
Nucula albensis, *d'Orb.*	–	–	–	x	
" bivirgata, *Sow.*	–	–	–	x	–
" pectinata, *Sow.*	x	x	x	x	x
" subrecurva, *Phil.*	–	–	–	x	–
Ostrea canaliculata, *Sow.*	x	x	x	x	x
Pecten (N.) quinquecostata, *Sow.*	–	–	–	–	x
Pleuromya gurgitis, ? *Brong.*	–	x	–	–	–
Plicatula pectinoides, *Sow.*	–	–	x	x	x
Trigonia Fittoni, *Desh.*	x	–	x	x	x
Palæocorystes Stokesi, *Mant.*	–	–	–	–	x
(Crabs not determined)	x	–	x	x	x
Epiaster ricordeanus, *d'Orb.*	–	–	–	–	x
Trochocyathus conulus, *Edw.*	–	–	–	x	–

The following is a list of fossils from the Zone of *Ammonites inflatus* in the Aube, Marne, and Ardennes, the first column showing how many of the species range up from the zone of *Am. interruptus.*

—	Range from Zone of Am. interruptus.	Clays of the Aube and Yonne.	Nodules de Talmat.	Gaize de l'Argonne.	Gaize de Marlemont.
VERTEBRATA.					
Polyptychodon interruptus, *Owen*	x	–	x	x	–
Lamna acuminata, *Ag.*	x	–	x	x	–
„ appendiculata, *Ag.*	x	x	x	x	–
Oxyrhina macrorhiza, *P. & Camp.*	–	x	–	x	–
Osmeroides lewesiensis, *Ag.*	–		–	x	x
Scapanorhynchus raphiodon, *Ag.*	x	–	x	x	–
CEPHALOPODA.					
Belemnites minimus, *List.*	x	–	x	x	–
Nautilus clementinus, *d'Orb.*	x	–	x	–	?
„ lævigatus, *d'Orb.*	–	–	–	x	–
„ radiatus, *d'Orb.* (? Albensis)	–	–	–	x	–
„ sowerbyanus, *d'Orb.*	–	–	–	x	–
Ammonites auritus, *Sow.*	x	x	x	x	x
„ candolleanus, *P. & Camp.*	–	x	x	–	–
„ catillus, *Sow.*	–	–	–	x	x
„ inflatus, *Sow.* (=rostratus, *Sow.*)	–	x	x	x	x
„ falcatus, *Mant.* (? cœlonotus)	–	–	–	x	–
„ Mantelli, *Sow.* (?)	–	–	–	x	x
„ raulinianus, *d'Orb.*	x	–	x	?	–
„ renauxianus, *d'Orb.*	–	–	–	x	?
„ splendens, *Sow.*	x	x	x	x	–
„ Studeri, *P. & Camp.*	–	–	x	?	x
„ selliguinus, *Brong.* (? lævigatus)	x	–	x	–	–
„ varicosus, *Sow.*	–	x	–	?	–
Anisoceras alternatus, *Mant.*	–	–	–	x	–
„ armatus, *Sow.*	–	–	x	x	–
„ moreausianus, *d'Orb.*	–	–	–	x	x
Hamites attenuatus, *Sow.*	x	–	x	–	–
„ intermedius, *Sow.* (=rotundus, *d'Orb.*)	x	–	x	x	–
„ virgulatus, *d'Orb.*	x	–	x	x	x
Baculites baculoides, *d'Orb.*	–	–	–	x	
„ Gaudini, *P. & C.*	x	–	x	–	–
Turrilites Bergeri, *Brong.*	–	–	–	?	–
„ puzosianus, *d'Orb.*	–	–	–	x	–
GASTEROPODA.					
Avellana clementina, *d'Orb.* (Ringinella)	x	–	–	x	x
„ hugardiana, *d'Orb.*	–	–	–	x	
„ incrassata, *Sow.*	x	–	x	–	–

—	Range from Zone of Am. interruptus.	Clays of the Aube and Yonne.	Nodules de Talmat.	Gaize de l'Argonne.	Gaize de Marlemont.
GASTEROPODA—*cont.*					
Avellana pulchella, *Price*	–	x	–	–	–
„ rauliniana, *d'Orb.*	–	–	–	x	x
Cerithium mosense, *Buv.*	–	–	–	x	–
„ vibrayeanum, *d'Orb.*	x	–	–	x	x
Aporrhais carinata, *Mant.*	x	–	x	–	–
„ Parkinsoni, *Sow.*	–	x	–	–	–
Dentalium decussatum, *Sow.*	x	x	x	–	–
Fusus acteon, *d'Orb.*	–	–	–	x	–
„ clathratus, *Sow.*	–	–	x	–	–
„ rusticus, *Sow.*	x	–	x	–	–
„ sp. (like trunculus, *Pict.*)	–	–	x	–	–
„ sp.	–	–	x	–	–
Murex bilineatus, *Pict.*	–	–	x	–	–
Natica gaultina, *d'Orb.* (=Genti, *Sow.*)	x	–	x	–	–
Pleurotomaria moreausiana, *d'Orb.*	–	–	–	x	–
„ Rhodani, *P. & Roux*	–	–	x	–	–
„ Thurmanni, *P. & Roux*	–	–	x	–	–
„ vraconnensis, *P. & Camp.*	–	–	x	–	–
„ sp. (like Margueti, *Rnv.*)	–	–	x	–	–
Rissoina incerta, *d'Orb.*	x		–	–	–
Solarium cirrhoide, *d'Orb.*	–	–	x	–	–
„ dentatum, *Sow.*	x	–	x	x	–
„ ornatum, *Sow.*	x	x	x	x	
„ rochatianum, *P. & Roux*	–	–	x	–	–
„ tingryanum, *P. & Roux*	–	–	x	–	–
Turritella alternans ?, *Röm.*	–	–	x	x	x
„ rauliniana, *d'Orb.*	x	–	–	x	–
„ vibrayeana, *d'Orb.*	x	x	–	–	
LAMELLIBRANCHIATA.					
Arca (Cucullæa) carinata, *Sow.*	x	x	x	x	x
„ „ æquilateralis, *Corn. & Bri.*	–	–	–	x	–
„ „ glabra, *Park.*	x	x	x	x	x
„ „ obesa, *P. & Roux*	x	x	x	–	–
Astarte (*cf.* dupiniana, *d'Orb.*)	–	x	–	x	–
Anomia radiata, *Sow.* ?	–	–	–	–	x
Avicula anomala, *Sow.*	–	–	–	–	x
„ gryphæoides, *Sow.*	–	–	–	x	–
„ rauliniana, *d'Orb.*	x	–	–	?	
„ subplicata, *d'Orb.*	–	–	–	x	–
Cardita dupiniana, *d'Orb.*	x	x	x	x	x
„ tenuicosta, *Sow.*	x	x	–	x	–
„ argonnensis, *Buv.*	–	–	–	–	x
Crassatella, sp.	–	–	–	–	x
Cyprina ligeriensis, *d'Orb.*	–	–	x	–	–
Exogyra (*see* Ostrea).					
Hinnites Studeri, *P. & Camp.*	–	–	x	–	–
Inoceramus sp. (like orbicularis), *Münst.*	–	x	–	–	–

	Range from Zone of Am. interruptus.	Clays of the Aube and Yonne.	Nodules de Talmat.	Gaize de l'Argonne.	Gaize de Marlemont.
LAMELLIBRANCHIATA—*cont.*					
Inoceramus propinquus, *Goldf.*	–	–	–	–	x
„ sulcatus, *Park.*	–	x	x	x	x
Isocardia cryptoceras, *d'Orb.*	–	–	–	x	–
Leda phaseolina, *P. & Camp.*	–	–	–	x	–
„ porrecta, *Reuss*	–	–	–	x	x
Lima albensis, *d'Orb.*	x	–	–	x	–
„ archiaciana, *Corn. & Briart*	–	–	–	x	–
„ parallela, *d'Orb.* (non *Sow.*)	x	–	x	x	–
„ rauliniana, *d'Orb.*	–	x	–	x	x
„ semiornata, *d'Orb.*	–	–	–	x	x
Lucina pisum, *Sow.*	–	–	–	x	–
Nucula bivirgata, *Sow.*	x	–	x	x	x
„ ovata, *Mant.*	x		–	x	–
„ obtusa, *Sow.*	x	–	–	x	x
„ pectinata, *Sow.*	–	x	–	–	–
„ renauxiana, *d'Orb.*	–	–	–	x	–
Ostrea canaliculata, *Sow.*	x	x	x	x	–
„ conica, *Sow.*	x	–	x	–	
„ haliotoidea, *Sow.*	–	–	–	–	x
„ Lesueuri, *d'Orb.*	–	x	x	–	–
„ frons, *Park.* (=macroptera, *d'Orb.*)	–	x	–	–	–
„ Naumanni, *Reuss.*	–	x	–	–	–
„ pectinata, *Lam.*	–	x	x	x	–
„ plicatula, *Lam.*	–	x	–	–	–
„ rauliniana, *d'Orb.*	x	–	–	x	–
„ sigmoidea, *Reuss*	–		–	x	–
„ vesicularis, *Lam.*	x	–	–	x	–
„ vesiculosa, *Sow.*	–	x	x	x	–
Pecten asper, *Lam.*	–	–	–	x	–
„ Dutemplei, *d'Orb.*	x	–	–	x	–
„ depressus, *Gold.* (? Beaveri)	–	x	–	–	–
„ cf. elongatus, *Lam.*	–	x	–	–	x
„ hispidus, *Goldf.*	–	x	–	x	–
„ Galliennei, *d'Orb.*	–	x	–	x	x
„ orbicularis, *Sow.*	x	x	–	x	x
„ raulinianus, *d'Orb.*	x	x	x	x	–
„ subdepressus, *d'Arch.*	–	x	–	–	–
„ Rhodani, *P. & Camp.*	–	–	x	–	–
„ subacutus, *dOrb.*	–	–	–	–	x
„ (Neithea) 5-costata, *Sow.*	x	x	–	x	x
Pholadomya, sp.	–	–		–	x
Pinna moreana, *d'Orb.*	–	–		x	–
„ Galliennei, *d'Orb.*	–	–	–	–	x
„ Neptuni, *d'Orb.*	–	–	–	x	–
„ tetragona, *Sow.*	x	–	–	x	x
Pleuromya acutisulcata, *d'Orb.*	x	–	x	–	–
„ astieriana ?, *d'Orb.*	–	–	–	–	x
„ mandibula, *Sow.*	–	–	–	–	x
„ plicata, *Sow.*	x	–	–	–	x
Plicatula pectinoides, *Sow.*	x	x	x	x	x

——	Range from Zone of Am. interruptus.	Clays of the Aube and Yonne.	Nodules de Talmat.	Gaize de l'Argonne.	Gaize de Marlemont.
LAMELLIBRANCHIATA—*cont.*					
Plicatula sigillina, *Woodw.*	–	–	–	x	–
Solen moreanus, *Buv.*	–	–	–	x	–
Spondylus gibbosus, *d'Orb.*	–	–	x	–	–
„ striatus, *Sow.*	–	x	x	–	–
Trigonia Elisæ, *Corn. & Briart*	–	–	x	–	–
„ Fittoni, *Desh.*	–	x	–	–	–
„ spinosa, *Park.*, var. subovata, *Lyc.*	–	–	x	x	–
„ sp.	–	–	–	–	x
Venus rotomagensis, *d'Orb.*	–	–	x	–	x
BRACHIOPODA.					
Rhynchonella compressa, *Lam.*	–	x	x	–	–
„ grasiana, *d'Orb.*	–	x	–	–	–
„ rectifrons, *Pict.*	–	x	–	–	–
„ sulcata, *Park.*	x	?	–	–	–
Kingena lima, *Defr.*	–	x	–	–	–
Terebratula dutempleana, *d'Orb.*	–	?	x	–	–
„ ovata, *Sow.*	–	–	x	–	–
Waldheimia sp.	–	–	x	–	–
CRUSTACEA AND ANNELIDA.					
Pollicipes unguis, *Sow.*	x	x	–	–	–
„ striatus, *Sow.*	–	x	–	–	–
Serpula antiquata, *Sow.*	–	x	–	x	–
„ gordialis, *Schloth.*	–	–	x	–	–
„ lævis, *Gold.*	–	–	x	–	–
„ plexus, *Sow.*	–	x	–	–	–
Vermicularia polygonalis, *Sow.*	–	x	–	–	–
ECHINODERMATA.					
Epiaster distinctus, *Ag.*	–	–	–	–	x
Holaster, sp.	–		–	–	x
Cidaris uniformis, *Sorign.*	–	x	–	–	–
„ Delatouri, *Cott.*	–	x		–	–
Pseudodiadema albense, *Cott.*	–	x	–	–	–
„ Dupini, *Cott.*	–	x	–	–	–
ACTINOZOA.					
Ceratotrochus insignis, *Dunc.*	–	x	–	–	–
Trochocyathus angulatus, *Dunc.*	x	–	x	–	–
„ harveyanus, *M. Edw.*	x	–	–	x	–

——	Range from Zone of Am. interruptus.	Clays of the Aube and Yonne.	Nodules de Talmat.	Gaize de l'Argonne.	Gaize de Marlemont.
SPONGIDA.					
Jerea pyriformis, *Lamx.*	–	–	–	x	x
„ mutabilis, *Defrance*	–	–	–	x	–
Retia costata, *Sollas*	–	–	x	–	–
Bonneyia sp.	–	–	x	–	–
Siphonia Fittoni, *Mich.*	–	–	–	x	–
„ pyriformis, *Goldf.*	–	–		x	–
HYDROZOA ?					
Parkeria sp.	–	–	x	–	

2. Central and Western Parts of the Paris Basin.

There can be no doubt that the beds which have just been described as representing our Selbornian stage along the eastern border of the Paris basin sweep westward beneath its central portion.

The continuity of this basin, however, is interrupted by an anticlinal flexure the axis of which runs in a direction from north-west to south-east. This is known as the "axis du Bray," and is believed to be a continuation of the anticline which runs through South Dorset and the Isle of Wight. A local *bombement* or bulging up of the anticlinal arch brings the Gaize, Gault, and Lower Cretaceous Series up to the surface along a tract of ground which is known as the Pays de Bray, and which may be described as a miniature Weald. It runs through parts of the Departments of the Seine Inferieur and of the Oise, from Neuchatel to Noailles, and the outcrops of the Gault and Gaize have a length of about 38 miles.

In this tract the beds dip steeply to the north-east, and are broken by a fault along that border, while on the south-west side they have only a slight inclination. In this respect the structure of the arch resembles that of the Isle of Wight, and still more that of the Vale of Wardour.

The stratigraphical succession in the Pays de Bray has been described by M. de Lapparent, and from his account[1] we learn

[1] Le Pays de Bray, 4to., Paris, 1879.

that the beds with which we are now concerned are as follows in ascending order:—

		Feet
1. Sables verts	-	66 to 130
2. Argile du Gault à *Am. Deluci*		20
3. Gaize à *Am. inflatus*		130 to 150

The greensands below the Gault clay appear to correspond with the sands of the zone of *Ammonites mammillatus,* but they have not yielded many fossils.

The overlying clay represents the zone of *Ammonites interruptus, A. Deluci* being a variety of that species. *Am. splendens* and other fossils also occur, and the clay forms a band of regular thickness from one end of the district to the other, though it is faulted out in places along the north-eastern border.

The Gaize, from M. de Lapparent's own descriptions, is evidently inseparable stratigraphically from the Gault; indeed, it is only the upper part which is really *gaize* (40 to 50 feet), the lower parts consisting of soft bluish micaceous marls which become more and more argillaceous towards the base, and to the north of Sommery the whole thickness consists of such marls without any true gaize at all. Where the Gaize is developed it resembles that of Argonne and the malmstone of England, being a friable siliceous rock, grey when damp, but drying to a whitish or yellowish grey, and remarkable for its porosity, lightness, and roughness. An analysis of a sample from Sommery gave the ollowing results:—

Silica soluble in potash	-	33·00
Insoluble silica		42·52
Alumina		1·57
Peroxide of iron		1·40
Lime		7·20
Magnesia	-	3·00
Loss by calcination	-	11·33
		100·00

The rock often contains harder lumps and siliceous concretions which are sometimes of a flinty nature, but, like those of our English malmstone, adhere to the surrounding mass, and do not separate themselves like the flints of the Chalk.

No fossils are recorded from the micaceous marls, nor are they common in the gaize, but *Ammonites inflatus, Am. auritus, Am. falcatus* ?, *Nautilus elegans, Pecten elongatus,* and *Plicatula* have been found.

Before leaving the central part of the Paris basin it will be convenient to give some particulars of two deep borings, both of which have traversed the clays of the Gault. The first of these is a boring at La Chapelle in St. Denis (Paris), which was

commenced in 1867 and finished in 1872. The second is a recent boring at Puys, near Dieppe.

The site of the Chapelle boring is 157 feet above the sea. It traversed the Parisian Tertiaries and the whole of the Chalk, and was carried to a depth of 718 metres (=2,355 feet), being successful in obtaining water from the sands beneath the Gault. The latest particulars of the beds referable to the Albian and Cenomanian in this boring are those recently published by Mons. G. F. Dollfus, from a special examination of marked samples in his possession.[1] The following is a translation of his account:—

	—	Thickness in Feet.	Depth in Feet.
Lower Chalk	Grey marly chalk with *Rhynchonella grasiana* and *Teredo? amphisbœna* -	—	Base at 2,046½
	Rather marly glauconitic chalk, with grey flints -	92	2,138½
Gaize and Gault	Very glauconitic blue clay, with *Pecten asper* - -	16½	2,155
	Fine grey marl, slightly micaceous	105	2,260
	Fossiliferous grey marl, *Pecten orbicularis* - - - - -	32½	2,292½
	Black fossiliferous marly clay with *Inoceramus concentricus*	20	2,312½
	Coarse glauconitic sand with phosphatic nodules; *Am. Deluci* (=*interruptus*), *Am. Raulinianus*, *Am. rotundus* -	Not stated.	—

I have grouped the beds according to my own views, for M. Dollfus regards the chalk with *Rh. Grasiana* at Turonian, and refers all the rest, except the coarse sand with *Am. interruptus*, to the Cenomanian! The black clay can hardly be other than Lower Gault, and the succeeding beds, including that with *Pecten asper*, seem comparable with the clays and marls of the Sussex facies of Gault. In all probability, the two highest divisions with a thickness of 121½ feet represent the Gaize and the zone of *Ammonites rostratus*, while the overlying beds seem to be the equivalents of our Chalk Marl.

If my view of the correlation is correct, and if the sands in which water was found belong to the zone of *Am. mammillatus*, the beds which represent our Selborinan stage have a total thickness of nearly 217 feet.

The boring near Dieppe, north-west of the Pays de Bray, was completed in 1897, and has been recently described by me from information communicated by M. Dollfus.[2] The site is at

[1] "Feuille des Jeunes Naturalistes,' Series III., Février, 1898.
[2] Geol. Mag., Dec. 4., vol. vii., p. 25.

an hotel close to the sea, north-east of Dieppe, and about 45 feet above sea-level. The beds traversed were as follows:—

	Description of Beds.	Thickness.	Depth.
		Feet.	*Feet.*
	Soil and Chalk (dug out)	9	9
Turonian.	White marly chalk - -	194·3	203·3
	Soft white chalk with a layer of grey marl	26·2	229·5
	Greyish chalk with flints	13·1	242·6
	Hard white chalk	47	289·6
Cenomanian.	Hard chalk	74·4	364·
	Grey chalk -	66·4	430·4
	Grey chalk with a layer of flints	48·4	478·8
	Greenish sandy clay [marl]	33·4	512·2
	Green sandy clay [marl] -	6·9	519·7
Gault.	Black clay -	135·1	654·2
	Green argillaceous sand	22·3	676·5
	Grey sand -	10·3	686·8
	Sandy black clay	6·7	693·5

From this it would appear that Gault clays were reached as soon as the base of the chalk was reached, and that the lower part of the Upper Gault is very sandy, the grey sand being clean quartzose sand and yielding a supply of water which overflowed copiously at the surface. The black sandy clay below may be regarded as Lower Gault, but as it was not pierced, the total thickness of the formation is not known. The thickness proved is over 174 feet.

In passing westward from the Pays de Bray beneath the Chalk, the light green sands thin out altogether, and the overlying beds are much reduced in thickness, for when they reappear in the neighbourhood of Havre the Gault and Gaize do not exceed 50 feet. At Cauville, about 7 miles N.E. of Havre, there is probably about 50 feet, but in the coast section between Octeville and Cap la Hève the thickness is everywhere less.

The following measurements were taken by Mr. W. Hill at a point nearly a mile east of Cap la Hève[1] :—

		Ft.	Ins.
Glauconitic Marl with phosphatic nodules—			
Gaize	Bluish-grey glauconitic marl with a course of hard siliceous doggers at the base - -	3	6
	Darker greyish-blue sandy glauconitic marl with doggers of hard siliceous stone -	7	0
	Dark blue-grey sandy marl with three layers of large siliceous doggers - -	4	9
	Blue-grey sandy and rather glauconitic marl with smaller concretions of siliceous stone	11	0
Gault	Very dark, nearly black, marly and glauconitic clay, with a layer of phosphatic nodules at the base - -	10	0
		36	3

[1] *See* Quart. Journ. Geol. Soc., vol. lii., p. 119, 1896.

Below the lighthouses of La Hève the thickness is still further reduced, the Gaize being about 24 feet and the Gault less than 4 feet, so that the total there is only 28 feet.

The Gault rests on a coarse pebbly brown sand with layers of ferruginous grit; this is 16 feet thick at the point where the above section was taken, but under the lighthouses is only 8 feet. It greatly resembles the Carstone of the Isle of Wight, and has been referred to the Gault by Hébert and other French geologists; its fossils are chiefly casts, and have not yet been worked out by anyone having acquaintance with the similar fossils of our English Lower Greensand, but *Ostrea aquila* (=*Exogyra sinuata*) is found in it, and Messrs. Lennier and Dollfus agree in considering the deposit to be of Aptian, not of Albian age.

The Gault has yielded very few fossils in this coast-section, but there can be no doubt that it is the attenuated representative of the zone of *Ammonites interruptus*, for the gibbose variety of that species (*Am. Deluci*) has been found in it.

The overlying Gaize is more fossiliferous, especially in the hard siliceous concretions, and M. Dollfus has recently published a list of the fossils obtained from these beds, from specimens in the Havre Museum and in the collections of Messrs. Fortin, Le Marchand, and himself. Mr. Hill found several which are not found in his list, and for the naming of which I am responsible. The following is a complete list of the fauna so far as it is known at present:—

Ammonites rostratus, *Sow.*
„ auritus, *Sow.*
„ raulinianus, *d'Orb.*
„ splendens, *Sow.*
„ mayorianus ?, *d'Orb.*
„ latidorsatus ?, *d'Orb.*
Nautilus albensis ?, *d'Orb.*[1]
Avellana incrassata, *Sow.*
Turbo Triboleti, *P. & Camp.*
Arca (Cucullæa) fibrosa, *Sow.*
Avicula rauliniana ?, *d'Orb.*
Exogyra conica, *Sow.*
Inoceramus concentricus, *Park.*
Lucina, cf. lenticularis, *Goldf.*
Ostrea canaliculata, *Sow.*
Ostrea vesicularis, *Sow.*
Pleuromya plicata, *Sow.*
Pecten orbicularis, *Sow.*
Pinna (two species).
Thetis Sowerbyi, *Röm.*
Trigonia heva, *Dollf.*
Rhynchonella convexa, *Sow.*
Cardiaster bicarinatus, *Ag.*
Epiaster crassissimus, *Defr.*
„ distinctus, *Ag.*
„ sulcatus, *Buc.*
Hemiaster difficilis, *Buc.*
Holaster lævis, *Ag.*
„ suborbicularis, *Brong.* ?
Pseudodiadema Normanniæ, *Cott.*

The assemblage of Ammonites is sufficient of itself to show that the Gaize of La Hève belongs to the zone of *Ammonites rostratus*, and that it is the equivalent of the Malmstone of Hampshire (*see* p. 111) and of the Gaize of Devizes (*see* p. 255). Here again, however, the fauna has some special local features, for the *Echinospatagus*, so common in our English beds, seem here to be replaced by species of *Epiaster*, which range upward into the overlying Cenomanian.

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[1] This species is given as *subradiatus*, d'Orb., by M. Dollfus (= *radiatus*, Sow.); but Messrs. Foord and Crick have shown that *radiatus* is a Lower Cretaceous species. *N. albensis* is a closely allied species occurring in the Upper Gault.

It is also noticeable that there is nothing near Havre which corresponds to our Chert beds or to the fossiliferous Warminster Greensand, with its numerous Pectens and small Echinoderms. As, however, these Chert beds and associated sands thin out and disappear to the north of Devizes, and also to the southward in North Dorset, and do not exist in our south-eastern counties, it can cause no surprise to find that they do not occur in France.

Passing across the mouth of the Seine to Honfleur, the Gaize is again found, and can be traced westward to Trouville, but is not discernible beyond that place.

Near Lisieux, which is about 18 miles south of Honfleur, there is a good section in a large sand-pit, which is recorded by Mr. Hill as follows (Op. cit. p. 127):—

		Ft.	*In.*
Sandy soil and rubble of cherts -	-	2	0
Very glauconitic and rather marly sand	- -	2	6
Dark grey greasy clay	-	0	9
Coarse brown pebbly grit with many light-brown phosphates and much fossil wood (*Carstone*) -	- -	7	0
Corallian, white micaceous sand	about	40	0

At the top of the grit and at its junction with the clay some fossils were obtained by M. Bigot, of Caen, who kindly sent them to us for inspection. They included *Ammonites interruptus* and var. *Deluci*, *Pecten orbicularis*, and *Cucullæa fibrosa* ?. Here, therefore, we have the zone of *Ammonites interruptus* on the point of thinning out, for it is only 9 inches thick, but it seems to persist as far up the valley of the Touques as the village of Fauvaque, where a small quarry showed glauconitic sand resting on a thin layer of clay, beneath which is the Corallian.

Beyond this the Gaize is represented by soft dark-grey glauconitic sand, passing up into greenish grey marly sand in which *Pecten asper* occurs occasionally. The combined thickness of these sands is only 10 or 12 feet, but they persist southward, and in the Departments of l'Orne and la Sarthe the band is known as the "*glauconie à Ostrea vesiculosa*," from the common occurrence of that shell.

At Vimoutiers there is from 7 to 9 feet of such sand, dark and argillaceous in the lower part, but a bright green sand in the upper part. M. Lecœur of Vimoutiers sent me in 1899 some small fossils which he had obtained from the upper part, and they are such as might occur in the highest bed of the Warminster Greensand. They include fragments of *Turrilites Bergeri*, *Ammonites Coupei*, *Pecten asper*, *Rhynchonella grasiana*, and *Porosphæra urceolata*. We have the authority of Mons. G. Dollfus for stating that near Le Mans this greensand contains the following species:—*Ammonites rostratus*, *Nautilus subelegans* (? *atlas*, Whiteaves), *Ostrea vesiculosa*, *Pecten asper*, and *Hemiaster bufo*. He regards it as the base of the Cenomanian, but he does not deny that it is the representative of the Gaize. In our opinion, if it represents

the Gaize (*i.e.*, the zone of *Ammonites inflatus*), it should be dissociated from the Cenomanian, and this was the view taken by M. de Lapparent in the second edition of his "Traité de Géologie" (1885), though in the third edition he recurred to the opinion held by M. Dollfus and others.

The changes which take place in passing westward beneath the Paris basin can also be traced along the southern border of the basin in tracing the outcrops south-westwards from Auxerres to Bourges. Part of the Gault clays are replaced by sands which form a lenticular mass, with a maximum thickness of about 400 feet, and are known as the Sables de Puisaye. These get thinner again in the valley of the Loire; at Sancerre the succession is as follows:—

	Feet
Sands and pebbly beds with *Am. rostratus* - -	36
Fine ferruginous sands (Sables de la Puisaye)	130
Micaceous clays with Gault fossils -	100
Coarse greensands -	30

North of Bourges the lower sands have thinned out, and a diminished thickness of Gault clay rests directly on the Aptian sandstone. At Vierson to the west this clay has disappeared, but the overlying sands and gravels continue and are overlain by glauconitic clays and marls with *Pecten asper*. The Gault sands can be traced to Gracay, but thin out to the south-west, and allow the overlying marls to rest on the Jurassic Rocks.[1]

This rapid thinning out along the southern outcrop is doubtless illustrative of what happens also beneath the whole of the south-western part of the Paris basin.

[1] See M. de Grossouvre, "Sur le Terr. Crét. dans le Sud-ouest du Bassin de Paris," Bull. Soc. Géol. France, Ser. 3. t. xvii. p. 475.

CHAPTER XXVIII.

PHYSICAL AND GEOGRAPHICAL CONDITIONS UNDER WHICH THE GAULT AND UPPER GREENSAND (SELBORNIAN) WERE DEPOSITED.

Geographical Conditions.

The history of the Upper Cretaceous deposits is the history of a great subsidence, and in order to understand how these deposits came to be spread out over such a wide area in western Europe, we must briefly glance at the geographical conditions which prevailed in this part of the world during the preceding epoch.

At the beginning of what we call the Cretaceous period the northern and north-western part of France, with Belgium, the Channel area, the southern part of the North Sea, and probably the whole of the British Isles, except parts of Yorkshire and Lincolnshire, was land: part of a continent which stretched eastward through the centre of Europe and westward beyond the present limits of France and Ireland.

This continent was bounded on the north by a sea which seems to have extended through Hanover and Holland, and across the North Sea into Yorkshire; but how this sea was connected with the open ocean we do not know. Neither do we know what lay to the far west; it is very generally assumed that the Atlantic Ocean existed then as now, but this is a pure assumption, and it is quite possible that the greater part of the North Atlantic was then land. To the south, however, we know that there was a large expanse of sea, which seems to have spread from Asia Minor, over the whole of the Mediterranean region, and thence through southern France and Spain, westward into the central Atlantic.

The Europe of the Cretaceous period was therefore very different from that of the present day; the great mountain ranges of southern Europe did not possess their present altitude, but its surface was diversified with ranges of hills, plateaux and lowlands, rivers and lakes. One tract of lowland, including at least one large lake, occupied an area extending through the south of England and a portion of north-eastern France west of the Ardennes, opening into a bay of the southern sea which lay over the region of the Jura, the Côte d'Or, and the Haute Marne.

During the progress of the Lower Cretaceous period, subsidence enabled the sea to creep up this tract of lowland, to enter the Wealden lake, and to occupy the south of England as far west as the centre of Dorset. At the same time the northern sea spread southwards through Lincoln, West Norfolk, and Cambridgeshire, finally uniting its waters with those of the southern sea across the middle of England.

The eastern limits of this sea are fairly well known from the evidence of deep borings, and its western limits can be inferred

with a high amount of probability. The Speeton clays thin out westward near Knapton, and do not reappear in South Yorkshire, being overlapped by the Red Chalk. Hence we may infer that the Lower Cretaceous sea did not spread so far west as the present boundary of the chalk. In Lincolnshire the Speeton series reappears and thickens as the Cretaceous escarpment trends to the south-east; its shore-line probably ran southward from the neighbourhood of Brigg to Sleaford, and thence toward the position of Bourn and Peterborough. Beyond this, however, it must have curved so as to trend south-west through the counties of Bedford, Buckingham and Oxford, but the nature of the deposits in these counties is such as to render it improbable that the sea extended much, if at all, beyond their western borders. From Oxfordshire the shore may have passed through a corner of Gloucestershire and through Wiltshire as far as Chippenham and Melksham, whence it turned southward again by Westbury to near Shaftesbury, and thence through Dorset to Lulworth (see p. 144).

Thus the general geography of the country may be depicted with a fair amount of certainty, and may be described as follows: Brittany was united to Cornwall and Devon across what is now the mouth of the English Channel, and formed part of a large area of land which included Wales, Ireland, and Scotland, with the north of England. Another tract of land stretched from central Europe, through Belgium, and the north-west border of France, into the east of England. And this land area was separated from the other by a narrow and shallow sea.

The eastern land was of the nature of a promontory or possibly a peninsula, and in all probability its general elevation above the sea at the time we are writing of was not great. The western land was much more extensive, and certainly included high ranges of mountains, with deep valleys and large rivers. Some of the rivers doubtless poured their waters into the sea which lay over central and southern England.

The subsidence of the Lower Cretaceous period seems to have been slow and gradual and its total amount seems to have been small. The change from the conditions of the Lower Cretaceous to those of the Selbornian was produced by a much more rapid and extensive subsidence. One result of this movement was the complete submergence of a large portion of that land which reached across the North Sea and terminated on the east of England. All that part of it which lay within the English limits was deeply submerged, so that the Gault mud which was deposited over its surface is of the same lithological character and has nearly the same average thickness as that which was deposited over the surface of the Lower Greensand to the south and north-west of it. Thus the thickness of the Gault clay beneath the western part of Essex varies from 150 to 170 feet; its thickness in West Kent is about 190 feet; and its thickness between Cambridge and Hitchin varies from 130 to 200 feet.

Eastward however the Gault thins somewhat rapidly; only 61 feet of it was found in the boring at Harwich and further

south at Wissant near Calais it is only 42 feet thick, and east of Calais deep borings have shown that it thins out altogether. Land therefore still existed in that direction, but lay entirely outside and south-east of English territory.

The subsidence of the Selbornian epoch also submerged a portion of the western land, carrying the sea over the surface of of the Jurassic and Triassic strata which formed the eastern margin of that land. There is reason to think, however, that the vertical extent of the downward movement was less in this region than in the east. The manner in which the Lower Greensand and Wealden seem to dip down together with the Jurassic beds below the overstepping Gault at Lulworth (see p. 144) suggests that the amount of subsidence was greatest to the east of this place, and the manner in which the Gault gradually oversteps all the members of the Jurassic series until it comes to rest on the Trias at Axmouth is proof that the movement was a tilt downward to the east.

The change in the lithological character of the sediment from "Gault" clays to Glauconitic sands is also evidence that the water was shallower to the west, and the coarse character of some of the sandy beds in the upper part of the stage shows that land was not very far away. In Devonshire too the uppermost beds near Sidmouth consist of shell-sand, *i.e.*, small angular fragments of shells without any glauconite, similar to deposits which are now found off our western coasts at depths of from 40 to 100 fathoms.

In attempting to restore the original extension of these deposits over the west of England, and thus to form some conception of the probable limits of the Selbornian sea in this direction, it will be convenient to begin in Devonshire, where the most westerly tracts of Greensand are preserved and where their nature and position afford definite evidence of the proximity of a shore line. These tracts are: (1) that of East Devon, which extends from the present coast line northwards to the range of the Blackdown Hills; (2) the two outliers of the Haldon Hills south-west of Exeter.

The relation of these tracts to the older rocks and the heights to which the base of the series attains will enable us to form some idea of their former extension both to the northward and to the westward. At Lyme Regis the base of the Selbornian rests on the Lower Lias; thence it passes westward across the Lias, Rhætic Beds and Trias, till on the Haldon Hills it lies on the Permian breccias, and must a little further west have abutted against the granitic rocks of Dartmoor.

From the cliffs of the coast west of Beer Head the base line rises inland into the Blackdown Hills, and if we take the outermost line of hills which runs northward from Sidmouth we find it rising gradually from 450 feet near Sidmouth, to about 780 on Blackdown east of Kentisbere, a distance of 13 miles; on Hackpen Hill to the north the base is below 700 feet, but rises again to 750 feet along the northern escarpment south of Wellington; another traverse further east shows a similar synclinal arrange-

ment, and it is probable that the Greensand extended northward in similar undulations to the Brendon and Quantock Hills, which rise at the present time to over 1,200 feet. Hence it is unlikely that the Greensand stretched over them.

Passing now to the Haldon Hills, we find the base line of the Greensand again showing a slight synclinal arrangement; for, so far as I can ascertain from the data at present available, the boundary runs at a level of about 620 feet on the south side of Little Haldon, drops to 550 feet on part of Great Haldon, and then rises to 700 feet at the north-east end. If we take the rise between the two extremities as an index, it shows one of 80 feet in 5 miles, and a prolongation of this would carry the base line to about 1,100 feet on Exmoor. Judging, however, from the undulations of level in the Blackdown Hills it is improbable that there was anything like a steady rise between Haldon and Exmoor, and consequently the height to which the Greensand rose on the borders of Exmoor is not likely to have exceeded 1,000 feet.

As Exmoor rises in several parts to over 1,200 feet, and in Dunkery Beacon to 1,700 feet, and as it must have suffered an immense amount of erosion since the Cretaceous period, we may feel sure that it was not submerged by the sea in which the lower beds of the Greensand was deposited, but stood well above it either as an island or a promontory.

It is clear, however, that if we restore a sheet of Greensand on a slope of from 700 to 1,000 feet above the lowlands of North Devon, there would be nothing to prevent its westward extension right across this part of Devonshire and through Bideford Bay into what is now the Bristol Channel, for no part of the country round Hatherleigh, Chumleigh and Torrington, reaches above 400 feet.[1] Consequently it seems probable that Exmoor, with the Brendon and Quantock Hills, formed an island or islands in the Selbornian sea.

Leaving the region of the Bristol Channel for a moment, let us return to Haldon and note its proximity to Dartmoor, where within 7 or 8 miles the ground rises to 1,200 and 1,500 feet, with greater heights to the westward. There can be no doubt that Dartmoor was land at this time, and that the coast line ran round its northern and eastern sides; and we have actual proof of its being under erosion in the tourmaline-bearing sand which forms the highest bed of the Haldon Sands. The worn and rounded form of the tourmaline grains in this sand is remarkable, for it must take much friction to wear down tourmaline crystals. Possibly the western side of the Dartmoor area was at this time bordered by dunes of blown sand, and the rounding of the tourmaline grains was effected in these dunes.

South of the valley of the Teign none of the hills are more than 500 feet high, and they bear no trace of Greensand *in*

[1] A patch of "Upper Greensand" was mapped by De la Beche, at Orleigh Court, N.W. of Torrington. This is re-assorted Cretaceous material, perhaps a Tertiary gravel. See Ussher, Quart. Journ. Geol. Soc., vol. xxxiv., p. 453, and Trans. Devon Assoc., vol. xi., p. 428.

situ, but looking to its height on Little Haldon, the probability seems very great of its once having stretched southward over the country around Torquay. There is, however, no evidence that it extended much farther to the south or south-west; the great gap of the English Channel is a feature of much later date, and the Greensand of Devon occupies a much more western position than any of the French outliers. The Channel Islands and the promontory of the Cotentin are remnants of the ancient land mentioned on p. 403 as stretching across the mouth of the Channel, and it is probable that the coast of the Upper Cretaceous sea, in passing from Devon to France, took an eastward curve which carried well to the north of the Cotentin.

Within the area of France itself the continuation of this coast-line in the time of the Lower Gault (zone of *Am. interruptus*) seems to have crossed the present coast near Trouville, and to have passed southwards near Lisieux in Calvados. The land which bordered this early coast line was, however, probably of low elevation, consisting, as it did, of Corallian Sands and Oxford Clay; so that much more of it was submerged by the sea of the Gaize. Sands of this age occur beneath the Cenomanian at Vimoutiers, Mortagne, Bellême, and Le Mans, and it is probable that they extended to the border of the Palæozoic region west of Argentan, Alençon, and Coulie.

Returning now to the area north of the Bristol Channel, we must remember that in early Cretaceous time this channel was probably a broad valley opening eastwards, and filled with strata of Triassic and Liassic age, remnants of which still remain both on the south side in Somerset and on the north side in Glamorgan. The Gault and Greensand, which rest on the Oxford Clay at a high elevation north-east of Wincanton, must have swept westwards over a large part of Somerset and across the surfaces of the Lower Oolites and the Lias far down the Bristol Channel. How far we have no means of knowing, but if Exmoor was an island, as seems probable from the considerations mentioned on p. 405, the end of the inlet must have lain somewhere to the west or north-west of Ilfracombe.

There is no reason to suppose that this inlet was the embouchure of a large river; it may have received some small streams from the western land; but so far as one can judge (*see* Map, Plate v.), it seems to have been a wide bay in the centre of which were several islands.

At the beginning of the epoch we are considering, that is when the area was first submerged beneath the sea of the Lower Gault, the Mendip Hills were probably also an island. The evidence for this is found in the following facts:—In Wiltshire, west of the Mendips, the Gault passes westward over the successive members of the Jurassic series from the Portland Sands at Great Cheverell to the Oxford Clay at Berkley, west of Westbury; but the rise of its base along this line of outcrop is not sufficient, if prolonged, to carry it over the Mendips.

Between Cheverell and Westbury the upper limit of the Gault is a well-marked line, and it keeps so nearly level that,

though slightly undulating, it is a little lower at Westbury than at Cheverell. From Westbury to Berkley it rises 150 feet in 4½ miles, and if we suppose this rise to have been continued to Warren House, north of Shepton Mallet (another 12 miles) the base of the Gault, which is at about 330 feet near Berkley would have run round Warren House Hill at a level of about 730 feet, the summit being now 979 feet above the sea.

As the sea deepened, however, the island would be nearly, if not quite, submerged; for the thickness of Gault and Greensand west of Warminster is over 200 feet, and the water in which the upper beds were deposited would probably have covered the Mendips. Coast erosion of these islands may account, however, for the unusual coarseness of the sand which forms the middle part of the Upper Greensand on the plateau between Warminster and Longleat; in some places, as in a pit in Bucklers Wood, east of Longleat Park, this sand contains small pebbles of quartz and lydianite.

In considering the further course of the coast-line through the west of England, we must remember that the Severn Valley was not then in existence, and that the Lower Jurassic strata were bedded up against the Palæozoic rocks of Monmouth and Hereford, which then, of course, rose to very much greater elevations than they do now. The Cretaceous sea gradually ate its way westward through the Jurassic rocks, as these were slowly bent down toward the eastern area of subsidence. The result was to produce a gently inclined plane of marine erosion, on which the basal Cretaceous sediments were laid down. There can be little doubt that the westerly transgression or overstepping of the Gault in North Wiltshire was exactly like that which we can see in South Wilts and in Dorset, and we may assume that from the surface of the Oxford Clay the overstep was continued across the Lower Oolites and over the Lias of Gloucestershire.

How far west the Cretaceous sea was carried at the close of the Selbornian epoch is a very difficult question to determine; because post-Cretaceous detrition has entirely removed all these deposits from the central parts of England. We are not, however, entirely without some evidence which will assist us in forming an opinion. We know that in the south-west the Greensand passes on to the Permian rocks, and probably, in places, extended beyond them onto Palæozoic rocks. It is most probable therefore that the Greensand passed completely over the Trias and Permian of the Midland counties, throughout all the lower eastern parts of Herefordshire and Shropshire.

The existence of outliers of Rhætic Beds in the north-east of Staffordshire and of Lias in the north of Shropshire suggest that the Jurassic series was once continued to the north-west in a succession of undulating flexures and that the south-easterly dip of the Jurassic strata in the counties of Warwick and Leicester is only part of one of this series of flexures. From the relation of the Cretaceous strata to the faults and flexures of the Jurassic rocks in the south-west of England, we may take it as very probable that the undulations of the Jurassics in the Midlands were largely

of pre-Cretaceous date and that there was a similar transgression of the Cretaceous base north-westward onto the Lias which then covered the plains of Cheshire.

It is worthy of remark that the outlier of Lias on the borders of Shropshire and Cheshire is on the same line of longitude as the tract between Dorchester and Bridport, where the Greensand rests on the Fuller's Earth, at an altitude which varies from 400 to 600 feet above the sea. It is not unlikely then that in the north of Shropshire the Greensand had reached about the same stage in its overstep and that it rested there on the Inferior Oolite. If this were so, we have only to replace the remainder of the Lias and most of the Inferior Oolite to find the level at which the Cretaceous base-line would come in over Shropshire.

It is well known that the Shropshire outlier includes Middle as well as Lower Lias, the former being visible at and near Prees Church; moreover, Mr. H. B. Woodward considers it possible that Upper Lias may just come in on the high ground to the southward, which is 380 feet above the sea.[1] The thickness of Upper Lias would probably have been about 150 feet, and if we give another 50 feet for Inferior Oolite, we get a level of nearly 600 feet above the sea as that at which an outlier of Greensand may possibly once have existed over this patch of Lias.

It may be objected that it is a great assumption to suppose that the removal of the Jurassic strata and the overstep of the Cretaceous had proceeded so far in Shropshire as it had in Dorset; that for all we know the Upper Cretaceous sea may not have extended so far to the north-west at this time as to reach Shropshire at all, and that it is rash to imagine the extension of the Gault and Greensand so far beyond their present line of outcrop.

To these objections the following rejoinders may be made:—(1) It is not only in Dorset that we have proof of the rapid overstep of the Cretaceous series across the deflexed members of the Jurassic system; the same transgression is seen in Wilts, and again in Yorkshire, where the Red Chalk comes to rest on the Oxford Clay. (2) It is significant that if we connect, by a line on the map, the places where the Gault attains its greatest thickness—in other words, if we ascertain the axis of greatest deposition—it runs from south-east to north-west from Eastbourne and Lewes through Windsor and Wendover, pointing directly to Shropshire and Staffordshire. (3) The great thickness of the Gault and Malmstone in the counties of Berks, Oxford, Bucks and Bedford, and the calcareous nature of the upper portion of the Gault in the two last, are proofs that the deposits along this line of outcrop were formed at a considerable distance from the coast of the Cretaceous sea. (4) There is the fact that Greensand, possibly of late Selbornian age, actually occurs in the north-east of Ireland, so that the Cretaceous sea appears to have reached that region toward the close of the epoch

[1] "Lias of England and Wales," Mem. Geol. Surv., p. 244.

The most probable way of access to that region is certainly by a channel across Cheshire. This route is more likely than that up St. George's Channel, because the latter probably owes its existence to a post-Eocene subsidence, the subsidence which followed the Eocene period of volcanic activity in Ireland and Scotland, and to which may be attributed the present low level of the Irish Cretaceous deposits.

Taking all these facts into consideration, it seems highly probable that in the later part of the Selbornian age the sea extended over the Cheshire plains and across the Irish Sea. We may also assume that, if we could restore the Selbornian deposits over the country toward the north-west, we should see a lateral lithological change similar to that which we can follow in tracing them to the south-west; the Upper Gault of Bucks and Bedford would pass into malmstone, and the whole would become more arenaceous and more glauconitic as it approached nearer to the western land.

With respect to the level at which it abutted against that land, there is much more doubt. It has been mentioned that an outlier of Greensand *may* have come in above the Lias of Shropshire at a level of less than 600 feet above the sea. It must be remembered, however, that the Lias outlier occupies the centre of a large synclinal area or basin, which was probably a pre-Cretaceous flexure like those in Dorset and in Yorkshire. The surface of marine erosion formed by the advancing Cretaceous sea would be planed across this basin, leaving much more of the Jurassic series in its centre than over its outer parts; thus it is quite as likely as not that some of the Oxford Clay was preserved in the centre of the basin, while its rim was planed down to the Lias.

Consequently, in our attempt to restore the extension of the Greensand over Shropshire, we must admit that we may have taken its base at too low a level, and that at least a part of the Oxford Clay may have come into the centre of the syncline. Now, the Oxford Clay of the Midland counties is from 300 to 400 feet thick, and if we add the lesser thickness to the 600 feet level we shall probably be nearer the mark. We thus arrive at a height of about 900 feet above the present level of the sea as the most probable horizon at which the base of the Greensand occurred in Shropshire and Cheshire.

If this conclusion is accepted as a fair calculation, we have a basis for restoring the coast-line of the Upper Cretaceous sea in this part of England, for within a certain distance of what we may call the Cheshire Straits we may draw the line round those parts which rise to more than 900 feet. We should, indeed, be safe in taking it round all the hills and ridges which rise to more than 800 feet, neglecting the modern valleys, which were not then in existence, for post-Cretaceous erosion has certainly removed more than 100 feet of material from the summits of the Shropshire and Derbyshire hills. Thus the valley of the Severn had no existence, except possibly as a short stream flowing north-eastward into the Cheshire Straits, and the Wrekin

was doubtless the end of a promontory which jutted out into those straits.

On the other side the coast would skirt the Pennine chain, where the Palæozoic rocks must have risen to a much greater relative height than they do now. From Manchester it would run by Macclesfield to near Falk, and thence eastward by the Weaver Hills and high above the Rhætics of Uttoxeter and Needwood Forest to Derby, whence it would pass northward in the direction of Sheffield, Leeds, and Knaresborough.

When we get into Yorkshire, however, we can no longer be guided by the level suggested by the occurrence of Lias and Rhætic beds in Shropshire and Staffordshire. We must seek for new evidence in the relation between the Cretaceous and Jurassic formations in that county, and the question arises whether the Red Chalk followed the slope of the Jurassic rocks up to the heights of the Yorkshire moors, which rise to 1,400 feet in Burton Head.

In the first place, it is certain that before and during the Cretaceous period the Jurassic strata must have stretched far to the north and north-west over what are now the valleys of the Tees and the Swale; and they must have risen to much greater relative heights in those directions, because we know that the principal flexures affecting the Jurassic rocks were produced before the time of the Red Chalk. Hence the great syncline of the Vale of Pickering and the uptilting of the beds which rise into the moors to the north were antecedent events. It is, of course, quite possible that the plane of erosion on which the Red Chalk rests was continued northward far on to the moors, but there are reasons which make it unlikely that it extended over and beyond them.

The rise of this plane from the Humber to Leavening is 600 feet in 25 miles, and a prolongation of this would not carry it to a greater height than 1,200 feet on Burton Head. The westerly rise from Speeton to Stragglethorpe is rather more rapid, namely, 550 feet in 20 miles; but we must remember that this is part of a synclinal curve and that the beds may have been continued nearly horizontally to the westward from Scragglethorpe and Leavening. In this connection also it is important to bear in mind the great diminution in thickness and the remarkable change in character which the formation exhibits in passing from east to west. At Speeton it is about 34 feet, at Scragglethorpe it is 10 feet thick and at Leavening only two feet, while at an intermediate locality, Wharram Grange, it is represented by only 18 inches of hard yellowish conglomerate rock, full of materials derived from Jurassic rocks. These facts led Mr. Hill to suggest that this locality was not far from the original limit of the deposit in a westerly and north-westerly direction[1]; he himself however remarks that the evidence is insufficient to base any decided opinion upon,

[1] "Quart. Journ. Geol. Soc.," vol. xliv. p. 360.

and I may mention the possibility of explaining the Wharram Grange deposit on the supposition that it marks the site of a submarine bank or shoal which was swept by a strong current; for, owing to the fact that rocks of various kinds entered into the composition of the sea-floor, it is probable that the surface of this floor was somewhat uneven.

All that can be said is that while it would be rash to imagine the Wharram Grange rock to indicate the near proximity of a coast-line, it is not probable that the Red Chalk extended indefinitely to the west or north-west. The great thickness of the Yorkshire Oolites, and the heights to which they reach at the present time, make it probable that they formed the shore-line of the Cretaceous sea in this part of England. It gives me pleasure to find that my colleague, Mr. Strangways, who has such an intimate knowledge of this region, takes the same view; he thus writes, "I agree with you as to the probable limited extension of the Upper Cretaceous beds towards the north; they probably abutted against the Jurassic mountains to the north-east."

It would appear therefore that the coast of the Cretaceous sea, which we traced up the eastern side of the Pennine chain to the neighbourhood of Leeds, passed thence in a north-easterly direction across Yorkshire to a point on the present coast near Whitby, and thence far out into what is now the North Sea.

Let us now review what has been discussed in the preceding pages, so as to gather into one view the probable geography of the sea in which the Gault and Greensand sediments were deposited. There can be no doubt that this sea lay between two large masses of land, and it seems probable that the western land was divided into two massifs—one in the west and south-west, of which Brittany, Cornwall, Wales and Ireland are the dismembered parts; the other to the north, including Scotland and the north of England, together with an extension into the North Sea, and ending southward in the Pennine promontory. The eastern tract of land occupied a part of Central Europe and stretched westward to the borders of France; its shore line appears to have run from Westphalia south of the Teutoburger Wald, through Holland and into the North Sea, bending then south-westward towards Kent, but again recurving sharply so as to run along the north-eastern border of France from Calais by Bethune, Douai and Avesnes to Mésières and Luxembourg.

On the south the sea was bounded by the great mass of Granitic and Palæozoic rocks which occupies the centre of France, but had an opening to the south-east over the Côte d'Or and the Jura to the larger Cretaceous sea of Southern Europe. It seems therefore that the part of the sea with which we are concerned curved round the eastern end of the central European land, that its width from this to the Pennine shore was not more than 200 miles, and that its width across the north of France was about the same; but that across the south of England it may have been some 280 miles from shore to shore. (See Map, frontispiece.)

Conditions of sedimentation.

We may next give some consideration to the nature and disposition of the sediments which were laid down in the sea we have delineated. The distribution of these sediments was thus; dark-coloured mud, which we now call Gault, was deposited throughout nearly the whole epoch round the eastern end of the European land. The greatest thickness of this mud was accumulated towards the central part of the sea from Bedfordshire to Berkshire, and thence south-eastward through the centre of Sussex and across the Channel to the departments of the Marne and Aube, in France.

South-west of this lay a tract where mud was only deposited during the time of the Lower Gault, the succeeding deposit being one which consists largely of silica derived from the remains of siliceous sponges, mixed with fine particles of sand, mica and glauconite, the proportions of organic and inorganic material varying in different places. Outside this and bordering the western coast-line sandy deposits of various kinds were formed, some fine and some rather coarse grained, but characterised as a whole by the abundance of glauconite grains, whence they are known as Greensand.

North of latitude 52° 50′ is another area, in which neither clay, nor malmstone, nor greensand were deposited, but a red chalky material, very thin in Norfolk and Lincolnshire, but thickening and becoming more marly to the north-east.

From this distribution of sediment I think we may infer that the western coasts were for the most part high and rocky, and that they were swept by a strong submarine current which did not allow anything finer than sand to accumulate on the sea-floor. On the other hand, the eastern part of the central European land was evidently low, and as it sank beneath the Selbornian sea it was overspread by muddy sediment brought by a current which was not strong enough to carry anything coarser than such mud. Further, it is clear that neither of these currents carried sediment into the northern part of the sea, and that there was a tract, including Lincolnshire and the North of Norfolk, where very little sediment of any kind was accumulated.

In what directions did the currents flow and whence came the supply of mud? These are difficult questions to answer, and we can hardly do more than indicate possible answers at present. It is fairly certain that the mud-bearing current did not come from the north or north-east; it is just conceivable that it came from the north-west down the Cheshire Straits, but the absence of Gault in Ireland is somewhat against this. The great thickness of clay in the east of England and France points rather to a current from the south-east, and the most probable source of the Gault mud seems to be material brought down by rivers draining the Belgo-Germanic land and carried northward by a marine current setting from the south-east, so as to deposit its load in the eastern and central parts of the Anglo-Gallic basin.

After a time the supply of mud grew less, till only a small quantity of suspended silt was carried by this current; in the clearer water siliceous sponges then began to grow, and small grains of glauconite were at the same time formed. The resulting deposit was a mixture of silt, sponge spicules, and glauconite grains, which we know as "Malmstone," and the French as "Gaize."

If, then, a warm mud-bearing current came from the south-east, a strong, colder current may have swept from the north along the western side of the sea and along the shores of the western land, till it lost velocity in the southern part of the sea, where it would be deflected eastward by the trend of the coast between Devonshire and the mouth of the Seine (See Map, frontispiece).

It remains only to consider the probable depth of the water below which the deposits of this stage were formed.

Mr. F. G. H. Price endeavoured to estimate this from a study of the Gault Mollusca,[1] assuming that the habitats of the fossil species were similar to those of the species which they most resemble at the present day. He arrived at the conclusion that during the time of the Lower Gault the depth at Folkestone was less than 100 fathoms, but that the Upper Gault (zone of *A. rostratus*) was formed in deeper water than the Lower Gault. This argument is open to the objection that the range of Cretaceous species was probably different from that of modern species of the same genus; but it is interesting to note that it does indicate a greater depth for the Upper Gault, for there are several lines of evidence which make that fairly certain.

Further, at the time Mr. Price wrote, much less was known about the bathymetrical distribution of the Mollusca. He could only take the range of the several genera as recorded by Dr. S. P. Woodward and Mr. Gwyn Jeffreys, whose books were published before the deep sea explorations of the last thirty years. It is certain, therefore, that an estimate made from the materials now available would give a different and more satisfactory result. Such an estimate would necessitate much research and much laborious calculation, but in order to form some idea of the probable result I have taken the Lamellibranchs only, and have tabulated the ranges of some of the genera found in the Gault of Folkestone, which exist at the present day. These ranges I have taken from two works which happened to be available namely, A. Locard's "Coquilles Marines au large des Côtes de France" (1899) and W. H. Dall's "Preliminary Catalogue of the Shell-bearing Marine Molluscs of the South-eastern Coast of the United States" (1889).

During the course of the investigation it seemed to me that in trying to estimate in this way the depth at which such a

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[1] "The Probable Depth of the Gault Sea," Proc. Geol. Assoc., vol. iv., p. 269, 1876.

deposit as the Gault was formed, we should bear in mind that it is not a pelagic deposit; and that if abyssal depths are reckoned in the averages a misleading result would be obtained. Thus if we are dealing with a deposit which is unlikely to have been formed at a depth of 1000 fathoms, it would be inexpedient to take note of the occurrences of any species or genus beyond that depth. The Gault is such a deposit, and, consequently, I have taken 1000 fathoms as the extreme limit of range; thus, in the case of species ranging from 1 to over 1000 fathoms, I have taken the average as 500. Every species for which the vertical range is given in the two books above mentioned has been thus averaged, and the mean of these averages has been taken as the mean range of the genus. Single occurrences of a species at depths near or over 1000 fathoms have been omitted.

The following is a tabular view of the results obtained, keeping the European and American data separate:—

Ranges of some Lower Gault genera.

—	American Coast.		French Coast.	
	Range in Fathoms.	Average.	Range in Fathoms.	Average.
Anomia	0 to 80	40	1 to 850	128
Arca (deep water species)	80 to 1000+	209	1 to 1000+	219
Astarte	5 to 1000+	190	1 to 450	131
Cardita	3 to 200	64	1 to 510	105
Corbula	3 to 805	118	1 to 250	50
Cuspidaria	50 to 1000+	398	30 to 1000+	378
Lima (excluding Limatula)	15 to 121	75	1 to 850+	222
Lucina	1 to 683	150	1 to 440	145
Nucula	5 to 1000+	486	1 to 1000+	267
Nuculana	7 to 1000+	478	1 to 1000+	375
Pectunculus	2 to 175	60	1 to 125	42
Pecten (deep water species)	1 to 1000+	350	1 to 1000+	172
Pinna	1 to 200	50	1 to 125	51
Tellina	0 to 640	66	0 to 560	85
Thracia	3 to 50	25	1 to 225	50

The mean of the first column of averages is 184; that of the second column is 154; and the mean of the two is 169. In other words this line of investigation leads to the conclusion that the depth of water during the formation of the Lower Gault of Folkestone was between 150 and 180 fathoms.

Ranges of some Upper Gault genera.

	American Coast.		French Coast.	
	Range in Fathoms	Average.	Range in Fathoms	Average.
Arca (deep water species)	80 to 1000+	209	1 to 1000	219
Astarte	5 to 1000+	190	1 to 450	156
Avicula	10 to 192	100	1 to 350	104
Cardita	3 to 200	64	1 to 510	105
Corbula	3 to 805	118	1 to 250	50
Hinnites	15 to 573	299	—	—
Lima	15 to 121	75	1 to 850	222
Nucula	5 to 1000+	486	1 to 1000+	267
Pecten (deep water species)	1 to 1000+	350	1 to 1000+	172
Pholadomya	—	—	1 to 1000+	413
Spondylus	60 to 640	350	1 to 550	148

The mean of the averages in the first column is 224; that of the second column is 185; and the mean of these two is 204. Whence we are led to conclude that the depth of water during the formation of the Upper Gault was about 200 fathoms.

The only other great class of animals which seems likely to afford satisfactory evidence of depth is that of the Foraminifera; and an attempt at eliciting this evidence has recently been made by Mr. F. Chapman.[1] The evidence furnished by these lowly organisms has moreover the advantage of being specific instead of generic. for in spite of the great variation of form which they exhibit, the species are much more persistent than those of more highly organised creatures, and many of them have continued to exist down to the present time.

With respect to his method of calculation, Mr. Chapman writes as follows:—"Those species from each zone of the Gault have taken which occur also in recent deposits, where their known depths have been accurately recorded. These depths have been carefully averaged for each species selected, and the total mean depth for all the species in each distinct zone of the Gault has been taken as the probable depth of its sea-bottom. In cases where there is a preponderance of common and well-developed forms, the evidence of such is considered to the subordination of occasional examples, which may have been introduced into the deposit by the action of currents. In obtaining the data from the recent species, attention has been especially paid to evidence of depth at which the particular species occurs most frequently and where it attains its best development." His results for the beds of the Lower Gault

[1] Natural Science, vol. xiii., p. 305 (1898).

work out to depths of from 700 to 1180 fathoms with a mean depth 830 fathoms. Those for the Upper Gault vary less, only from 820 to 910 fathoms, with a mean depth of 866 fathoms.

It will be noticed that these depths are greater than such as anyone has hitherto thought probable, and, further, that the indication of greatest depth occurs in the Lower Gault, which is contrary to the inference deducible from all other lines of evidence. These considerations induce me to believe that there is some flaw in the method of calculation adopted by Mr. Chapman. It appears certain from the figures given that he has not hesitated to bring records from great depths into his account, and it is doubtless these depths which have raised his averages to such high figures.

He himself notes that the mean resultant depths are greater than all previous estimates founded upon a consideration of higher organisms, and he offers the following explanation: "Although the bathymetrical range of these larger forms is in most cases rather limited to the shallower parts of the ocean, it appears to me extremely probable that current action, of which there is abundant proof throughout the Gault at Folkestone, has there operated in bringing together assemblages of testaceous remains from the higher continental slope on which they flourished to greater depths where these accumulations took place." That some small and light shells may have been introduced into the Gault mud in such a manner I would not deny, but seeing that most of the bivalve Molluscs of the Gault occur with very perfect and united valves, I think it is almost certain that they lived and died on the spot where they are now found. These Molluscs, so far as can be judged from their generic affinities, clearly indicate a much less average depth than that arrived at by Mr. Chapman's consideration of the Foraminifera.

The only other criterion of depth is a comparison with the depths in which such deposits are being formed in modern seas. So far as mud resembling that of the Gault is concerned, this will not help us much, for where large rivers debouch into the sea mud is carried to great distances and sometimes into great depths. It is noticed, however, by Mr. Hill (see pp. 337 and 338) that the quartz-grains in the clays of the Folkestone Gault are very minute. Those in Beds 2 to 11 are seldom larger than ·15 or ·18mm. and are comparable in size to those found in modern muds between 300 and 600 fathoms. Those in Bed 13 average from ·05 to ·08, and are such as might be found in 1,000 fathoms or even greater depths.

The Upper Gault of Folkestone, however, contains a bed of glauconitic sand, and further west such sands replace the whole of the Upper Gault. The formation of glauconite goes on within more restricted limits. The grains are formed in the hollow spaces of various calcareous organisms, but especially in the chambers of Foraminifera. They are generally associated with terrigenous materials, either with mud (forming the green muds of Murray and Renard), or with sand (forming greensands). Prof.

A. Agassiz has observed,[1] "The greensands are generally found along continental coasts where the fine silt from rivers is not very abundant, as, for instance, off the Shetland Islands, off the Cape of Good Hope, off Japan, Australia, and some parts of the east coast of North America." Off the coast of Georgia and South Carolina the patches of greensand occur in depths of from 50 to 150 fathoms; off the west and south coasts of Australia it forms a continuous belt between 50 and 400 fathoms; and off the Cape of Good Hope it extends down to 500 fathoms. It does not occur at great depths nor at great distances from large land areas.

Where glauconite is associated with large grains of quartz we may be sure that land was not far off, and that the depth of water was not great, but where it is associated with numerous sponge spicules and with very fine silt or sand, the probability is that the deposit was formed at a greater distance from land and in water of more than 100 fathoms. The greater part of what is usually called Upper Greensand consists of such fine-grained materials—and this is notably the case with Malmstone—in which sponge spicules or the silica derived from them often make up 50 per cent. of the rock material.

Sir John Murray states that the spicules of sponges rarely make up more than 1 or 2 per. cent. of a deep-sea deposit, except in limited areas, where extensive growths of such sponges are found, when the quantity of spicules in some samples amounts to as much as 20 per cent.[2] He gives examples of such patches of siliceous sponges in depths ranging from 100 to 530 fathoms, and observes, "On the whole, siliceous sponges are most abundant in moderate depths on the Blue Muds, along continental shores and in pelagic deposits."

Prof. Agassiz also testifies "that siliceous sponges are often found in great numbers, as in the globigerina ooze of Santa Cruz (one of the West Indies) where . . . . the whole mass of the mud was so thoroughly impregnated with spicules and with sponge sarcode as to be sticky and viscid. More than once the dredge must have plunged headlong into one of the ubiquitous sponge-beds, the glairy mass, like white of egg, with a multitude of spicules distributed like hair in mortar throughout the mud."[3] The depths from which these hauls were made is not given, but it is stated on p. xiv. that it was in comparatively shallow water, and from the map it would seem to have been between 200 and 500 fathoms.

From the facts above mentioned, I think we may conclude that beds of fine grain in which sponge spicules are abundant, such as Malmstone and Gaize, and the Chert beds of higher horizons, are not likely to have been formed in water of less than 100 fathoms, and the depth is more likely to have been 150 or 200 fathoms in the central parts of the sea. The tendency of

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1 "Three Cruises of the *Blake*," vol. i., p. 264.

2 Murray and Irvine, "On Silica and Siliceous Remains in Modern Seas," Proc. Roy. Soc. Edin., vol. xviii., p. 230.

3 "Three Cruises of the *Blake*," 1888, vol. i., p. 149.

modern siliceous sponges to grow in dense patches or sponge fields, between which the sea-floor is comparatively free from such sponges, probably accounts for the very local manner in which the fossil sponge-beds and layers of Cherts are developed, and for the complete absence of such beds between two areas in which they occur.

Toward the close of the period some change seems to have taken place in the western part of the sea which altered the set of the currents, so that coarse sand was carried farther out to sea than it previously had been. Coarse sand occurs even below the Chert beds in the Vale of Warminster, and large grains of quartz and glauconite occur in the highest sands throughout South Wiltshire. They are also found in the top sandstone of Western Dorset, which passes, with similar characters, into Somerset (Chard) and into East Devon. In Dorset and Devon also the sandstone terminates in a current-worn surface.

Coarse sand and current action are generally associated with shallow water, but the superposition of coarse sand upon finer material does not necessarily indicate elevation of the sea-floor and closer proximity to land, for other physical changes can produce the same result. In this case it is probable that the gradual submergence of the Mendips, the Quantocks and Exmoor, and the conversion of the two latter into an island, may have been the cause. The rocks of these areas would supply plenty of sand, and a strong easterly current might be set up along one side of the Quantock-Exmoor island, sweeping the coarse sand of its shores much farther to the east and south-east than it had previously been carried.

CHAPTER XXIX.

ECONOMIC PRODUCTS AND WATER SUPPLY.

Building Stones.

The arenaceous parts of the formation which are usually known as Upper Greensand contain beds of stone which have been extensively quarried for building stone and other constructive materials, such as "firestone" and "hearthstone."

These stone beds have been quarried in Surrey, Hampshire, Sussex, Wiltshire, Dorset, the Isle of Wight, and to a less extent in Devon; they occur also in Berkshire and Oxfordshire, but have not been worked in those counties.

It will be convenient to describe the building materials which have been obtained in each of the counties above mentioned, and the following accounts have been compiled from various sources.

Surrey.

The stone quarried in Surrey is principally of the kind known as "firestone," that is, a fine-grained sandy stone containing a large amount of colloid silica, soluble in alkaline solutions. The chief quarries are at Godstone, Merstham, Reigate, Gatton and Betchworth, but those of Reigate and Gatton are not now worked.

The position of the firestone and its general characters have been described on pp. 93 and 97.

Mr. Webster, who described the stone in 1819 under the name of "Reygate stone," remarks that "the quarries of Reygate stone were formerly considered of such consequence that they were kept in the possession of the Crown, and a patent of Edward III. exists authorising them to be worked for Windsor Castle. Henry the Seventh's chapel at Westminster was also [? partly] built of the stone procured from them, as is also the church at Reigate."[1]

As a general building-stone, however, it does not seem to be very durable—at any rate, under the conditions to which it is exposed in London. In former days large quantities were brought from Reigate and Godstone for the construction of important buildings in London, but Mr. C. H. Smith said[2]: "Of these buildings there were now scarcely any parts remaining; some of the upper portions of Westminster Abbey, about the cloisters, and the interior parts in Dean's Yard, were the only relics. Sir Christopher Wren, speaking of Westminster Abbey

[1] Trans. Geol. Soc., vol. v., p. 353 (1821).
[2] Proc. Geol. Assoc., vol. i., p. 210 (1862).

in his day, described it as having mouldered away four inches from its original surface."

The stone is soft and easily dug from the quarry, but hardens on exposure to the air, if kept under cover and protected from the rain and sun. It is stated that the weight of the stone, in its ordinary state, is 103 lbs. per cubic foot, or 21¾ cubic feet to the ton.[1]

No complete analysis of the rock in this district has ever been made, but Messrs. Paine and Way state that they found 40 per cent. of soluble silica in a piece of firestone from Merstham.

Mr. Rudler informs me that on visiting Merstham a few years ago he found that the local stone had been recently used in restoring the doorway of Merstham Church. There is a specimen of Gatton stone among the samples of building stones in the collection at Jermyn Street, with a note that it has been employed in Hampton Court, Windsor Castle, in the Town Hall and Alms-house at Croydon, and in many churches in Surrey.

Hampshire.

The Malmstone of Farnham has been described by Messrs. Pain and Way, whose account has been quoted on p. 108. They mention two beds in the upper part of the formation as having been used for building-stone—(1) the white building-stone or firestone, a purely siliceous rock with over 50 per cent. of soluble silica and about 20 feet thick; (2) the *blue* building-stone, underlying the *white*, a calcareous stone containing about 75 per cent. of carbonate of lime. The latter is probably the bed (4½ feet thick) which is still quarried for building-stone at Dippenhall Farm (*see* p. 109).

Similar beds, both siliceous and calcareous, have been quarried since very early times in the neighbourhood of Selborne, and are thus described by Gilbert White,[2] who calls it *freestone.* "This stone is in great request for hearth-stones and the beds of ovens; and in lining of limekilns it turns to good account, for the workmen use sandy loam instead of mortar, the sand of which fluxes and runs by the intense heat, and so cases over the whole face of the kiln with a strong vitrified coat like glass, that it is well preserved from injuries of weather and endures thirty or forty years. When chiselled smooth it makes elegant fronts for houses, equal in colour and grain to the Bath stone, and superior in one respect, that when seasoned it does not scale. Decent chimney-pieces are worked from it of much closer and finer grain than Portland; and rooms are floored with it, but it proves rather too soft for this purpose.

"It is a freestone cutting in all directions, yet has something of a grain parallel with the horizon, and therefore should not be surbedded [*i.e.*, set on end], but laid in the same position that it

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[1] Report on the Selection of Stone for Building the New Houses of Parliament (1839).

[2] "Natural History of Selborne," Letter IV.

grows in the quarry. On the ground abroad this firestone will not succeed for pavements, because probably some degree of saltness prevailing within it the rain tears the slabs to pieces. Though the stone is too hard to be acted on by vinegar, yet both the white part and even the blue rag ferment strongly in mineral acids.

"Though the white stone will not bear wet, yet in every quarry at intervals there are thin strata of blue rag which resist rain and frost, and are excellent for pitching of stables, paths and courts, and for building of dry walls against banks, a valuable species of fencing much in use in this village, and for mending of roads. This rag is rugged and stubborn, and will not hew to a smooth face, but is very durable; yet as these strata are shallow [*i.e.*, thin] and lie deep, large quantities cannot be procured but at considerable expense."

Topley observes that the "blue rag" mentioned by Gilbert White is a siliceous limestone, which sometimes passes into a very cherty stone, and is then harder and has a more splintery fracture; but it is seldom found in thick enough beds to serve well for building purposes.[1]

Sussex.

The Malmstone extends westward for some distance into Sussex, but is not quarried for any purpose at the present day. It appears, however, to have been worked as far back as Roman times, for "it has been used in the Roman villa at Bignor, not only for ordinary masonry, but also, polished, in the fountain (?) which is in the centre of the largest room. In this form," says Mr. Topley, "it makes an excellent marble, which I have not elsewhere seen employed."[2]

Near Eastbourne, where the Upper Greensand is nowhere more than 40 feet thick, it contains beds of greenish calcareous sandstone which were formerly quarried for building. Mr. Topley observed that Pevensey Castle was partly built of this stone. He also notes that the ancient catapult balls found in the neighbourhood of Pevensey and Eastbourne are made of this sandstone (Op. cit., p 372).

Isle of Wight.

A bed of sandstone, locally called the *freestone*, lying below the Chert beds and about 4 feet thick, affords a good building-stone. Mr. Strahan remarks, "This bed has been worked from time to time through a large part of its outcrop in the central and southern parts of the Island, but the principal quarries now in use lie around Shanklin, Bonchurch, and Ventnor."[3] The beds above and below it are worked for firestone and hearth-stones.

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1 "Geology of the Weald," Mem. Geol. Survey (1875), p. 372.
2 "Geology of the Weald," p. 372.
3 "Geology of the Isle of Wight." Mem. Geol. Survey, 1889, p. 253.

Mr. M. Norman[1] states that this freestone can be sawn into blocks, and into lengths for mullions; also that "Steephill Castle is decorated with grotesque corbels over its doors and windows carved out of it." It appears to be a durable and serviceable stone, for the same author observes that most of the houses in Ventnor, Bonchurch, St. Lawrence, and Niton are built of it, as well as St. Lawrence Church, two churches at Ventnor, and the new one at Bonchurch.

Wiltshire and Dorset.

At Potterne, near Devizes, a bed of dark-grey compact and fine-grained sandy limestone has been quarried from time to time for building-stone (see p. 251). It was used largely in the building of Blounts Court at Potterne, and is believed to be very durable. There is, however, no great thickness of it, the bed seldom exceeding 2 feet, and being merely a single layer with soft sand above and below.

Other beds of rougher and less compact stone occur in the Vale of Pewsey (see p. 262), and have been used locally in building cottage and garden walls.

A bed of hard glauconitic sandstone cropping out at Dilton, near Westbury, has been used for the masonry of the railway bridges near that place. At and near Maiden Bradley beds of sandstone in the Chert beds have been used as a building-stone.

In the Vale of Wardour there is a thick bed of rather coarse glauconitic stone which in former days was extensively quarried at many localities, but is not now worked. Its position has been described in Chapter XVI., and its thickness varies from 10 to 14 feet. It is a massive stone, would probably work freely, and large blocks could certainly be obtained; it consists of quartz and glauconite grains with a cement of crystalline calcite. I did not learn whether it was regarded as a durable stone, nor why its use had been abandoned.

Dr. Fitton says it was called "Greenstone" at Fovant, and adds, "It is valuable from its not being affected by frost. It can therefore be dug in any season, and stands well in water, as in the foundations of bridges, and in exposed situations, as in copings, etc."

The same sandstone extends southwards to Shaftesbury and Melbury. It has been largely quarried near Shaftesbury, and is still used both for building and for road metal (see p. 159).

At Melbury, what appears to be a better bed of building-stone occurs at a higher horizon, and is quarried on the north side of Melbury Hill. This is a fine-grained, greenish-grey sandstone, which is very soft in the quarry, and can be easily worked as a freestone; on exposure to the air it hardens. I was informed that it had been largely used in the construction of Trinity Church, Shaftesbury, and used for coping-stones to the wall along

[1] "Geological Guide to the Isle of Wight," 1887, p. 85.

the Park at Iwerne House (Lord Wolverton's). The quarry shows six feet of this stone without proving its base, and if it proves durable it would probably be worth more extensive exploration. It probably extends for a certain distance both to the north and south-west of Melbury, but does not reach so far as Iwerne.

The only other part of Dorset where I have seen Upper Greensand quarried for building-purposes is along the escarpment from Bingham Melcombe to Dogbury Hill, north of Minterne. The bed is a hard glauconitic sandstone with calcareous cement, forming the topmost bed of the Greensand immediately below the chalk. It has been used in the construction of houses and farm buildings on the high ground near its outcrop, and is apparently a good building-stone. Its thickness averages about 6 or 7 feet, and it includes many phosphatic nodules and phosphatised fossils in its upper part, which appear as included brown lumps breaking with the stone, just like flints in plum-pudding-stone. They do not appear to detract from the quality of the sandstone.

Devonshire.

Sandstones in the upper or chert-bearing part of the Greensand have been quarried for building-stone in several parts of East Devon.

On Snowdown Hill, near Chard, there are quarries whence much stone has been extracted, but they are not now quarried.

Again, at Branscombe, there are several quarries where the highest sandstone at the top of the Chert beds has been quarried, and from which stone is still taken for local use.

At Salcombe, near Sidmouth, there are extensive quarries in a yellowish sandstone near the top of the formation. This lies in massive beds, and is free from cherts, so that it can be taken out in large blocks, and worked as a freestone. The principal quarry, east of the church, was worked until about 1860, according to Mr. H. B. Woodward,[1] and it is stated that much of Exeter Cathedral was built of this stone. Salcombe Church and the churches in several neighbouring parishes are built of it. There is another and more recent quarry south of the church, on the eastern slope of Salcombe Hill. It has also been quarried at Dunscombe, and large squared and dressed blocks still lie in the quarry near Dunscombe Farm. The rock is a calcareous sandstone without any glauconite grains, and the portions exposed to the air are very hard, so that it is probably a durable stone.

Soluble Silica and Artificial Stone.

The malmstones and firestones with their associated sands in Surrey, Hampshire, and other counties, contain a form of silica which is soluble in alkaline solutions. The existence of this soluble silica was first pointed out by Messrs. Paine and Way in

[1] Geology of England and Wales, 1887, p. 394

1846,[1] and the amounts of such silica found by them in different parts of the Upper Greensand near Farnham have been quoted on a previous page (p. 108.) In some samples it ranges to as much as 70 per cent., and is not uncommonly from 40 to 50 per cent.

The microscopic appearance of this silica has been described by Dr. Hinde (see p. 356), and it has since been found to exist in greater or less quantity in the rocks known as malmstone and gaize, wherever these occur in England and France. It also occurs in the fine spicule sands which form layers in the Chert Beds of Wilts and Dorset.

Messrs. Paine and Way recommended its use as a top-dressing for soils on which wheat and other cereals were grown, but its effect in strengthening the straw has not been found to come up to their expectation.

Another use for it has, however, been discovered, namely, for the manufacture of certain artificial stones in which silica is wanted to be converted into silicate of lime. It was first employed for this purpose by Mr. F. Ransome, who made a stone which he called *Apœnite*, by treating a mixture of Farnham malm, sand and chalk (or other calcareous material) with a solution of silicate of soda.

When these materials are mixed together a chemical action takes place, which Mr. Ransome believed to be as follows:—"The silicate of soda is decomposed, the silicic acid being liberated combines with the lime and forms silicate of lime, while a portion of soda in a caustic condition is set free. This caustic soda immediately seizes upon the soluble silica which constitutes one of the ingredients, and thus forms a fresh supply of silicate of soda, which is in its turn decomposed by a further quantity of lime and so on."[2]

When freshly mixed, the material can be moulded into any required form, and it gradually hardens as the formation of silicate of lime goes on, till at length the mass is converted into a compact stone, which is capable of bearing very great pressure, and which is stated to wear well, both in hot and cold climates. The weight of this stone is about 137 lbs. per cubic foot.

The expense of making Apænite and other artificial stones is a bar to their extensive use for ordinary blocks, "but the facility with which it can be moulded to the most intricate forms, makes it very economical when it is required to take the place of carvings or other enrichments in natural stone."[3]

A receipt for making this stone is as follows:—five parts of sand, one of Farnham rock, $1\frac{1}{4}$ of Portland cement, and the same proportion of silicate of soda. (Op. cit. p. 75.)

Victoria Stone is another variety of it, made from powdered granite, Portland cement, and silicate of soda.

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[1] See Journ. Roy. Agric. Soc., vol. xii., p. 544.

[2] See Reports Brit. Assoc. for 1872, Trans. Soc., p. 248.

[3] Notes on Building Construction, vol. iii., p. 74. Rivingtons.

The silicate of soda is made by boiling ground Farnham stone in cream caustic soda.

A mixture of four parts of crushed granite with one of Portland cement is allowed to set for three days or more, into a hard block moulded to the required shape. It is then immersed in the silicate of soda for some seven or eight weeks. The lime in the cement acts upon the silicate, and by the silicate of lime thus formed the whole mass becomes indurated.

Victoria stone has been used chiefly for paving, and is said to be cheaper and more durable than Yorkshire flagstones. It weighs from 140 to 160 lbs. per cubic foot. It has also been used for window-sills, coping stones, caps for piers and in other moulded forms.

It has been used for the whole of the external stonework (except the cornice) at Fresh Wharf, London Bridge; for the chimney shafts in Messrs. Peek and Frean's biscuit manufactory at Bermondsey, and for paving-stones in many parts of London.[1]

Bricks, Tiles, and Pipes.

The Gault has been largely dug for brickmaking, and brickyards have been opened in it wherever there was a local demand for bricks. There are also many large permanent brickyards which not only supply the wants of neighbouring towns, but export bricks to London and other places.

Both the Lower Gault clays and the Upper Gault marls are employed for brick-making, though they differ considerably in chemical composition. So far as we can learn the upper clays and marls produce the best bricks because they contain more carbonate of lime, while the Lower Gault is best for tiles.

A good brick-clay should contain a certain amount of fine sand and a fair amount of carbonate of lime, in addition to the pure clay or silicate of alumina of which it is largely composed. If these ingredients are not present in the natural clay they have to be added in suitable proportions.

The presence of the sand prevents the brick from cracking, shrinking, and warping, as it would do if made from pure silicate of alumina; but an excess of sand makes the brick brittle. Carbonate of lime has a twofold effect, "it diminishes the contraction of the raw bricks in drying, and it acts as a flux in burning, causing the grains of silica to melt, and thus binding the particles of the brick together" by the formation of a silicate.[2]

The carbonate of lime, however, must be in a very finely divided state; lumps or concretions of carbonate of lime such as frequently occur in clays and are often called "race," should be picked out carefully, as when burnt they form quicklime, and by absorbing moisture split the brick into pieces.

When carbonate of lime is added to a clay it is generally in

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1 Quoted from Notes on Building Construction, vol. iii., p 75.

2 Notes on Building Construction, vol. iii., p. 86. Rivingtons.

the form of powdered chalk; an excess of lime causes the brick to melt and lose its shape.

There is, however, a wide margin for the proportions of all these ingredients. A good brick-clay may contain from 10 to 25 per cent. of fine sand, from 6 to 30 per cent. of carbonate of lime, and from 45 to 70 per cent. of silicate of alumina.

In ordinary analyses the silica which exists as sand is not shown separately from that which is combined with the alumina, and thus they are not so useful as they might be in determining the value of a clay for brickmaking. A rough estimate may however be made, on the assumption that the alumina is present as a hydrated bisilicate of alumina, the proportion of silica in combination being as 46·6 to 39·5. In many clays much of the silicate of alumina is present as finely divided mica, but common muscovite mica has from 45 to 48 per cent. of silica, and from 30 to 36 per cent. of alumina.

Analyses of Gault clays show that water of combination is always present in quantities varying from 4 to 13 per cent., an indication that much of the alumina is present as a hydrated silicate. The Upper Gault clays generally contain a sufficient amount of carbonate lime; but they are deficient in free sand, so that some is usually added to the clay for making bricks.

Gault bricks are generally of very good quality, hard throughout and very durable, but they are difficult to cut when half bricks are wanted. They are also heavy, and to remedy this the brick is either perforated, or a hollow is made on one side and this is technically called a "frog."

The stronger Gault clays, especially those of the Lower Gault which contain less carbonate of lime, are suitable for making tiles and agricultural drain pipes, and for these the clay is generally used without any addition of sand.

Bricks made from the natural Gault clays and marls are almost always pale coloured—either white or pale yellow,—but the inferior sorts are sometimes mottled with pink or red, these colours being due to some partial oxidation of the iron in the process of baking or burning. The lowest part of the Gault, however, sometimes makes red bricks.

What are known as *Suffolk White Bricks* are made from the Gault clay at Hitchin and elsewhere. "They contain a very large proportion of sand, which makes them useful for rubbers.[1] They are rather soft for ordinary building purposes, but harden in time, which is attributed to the silicic acid in the clay acting upon the chalk [calcium carbonate], so as to form some of it into silicate of lime."

The Burham Brick, Lime, and Cement Company, the Aylesford Brick and Tile Company, the Dunton Green Brick and Tile Works, the Arlesey Brick and Cement Company, and the brickyards at Barnwell near Cambridge, are some of the largest

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[1] Notes on Building Construction, vol. iii., p. 107: "'Rubbers' are bricks made sufficiently soft to be cut with a trowel to any required shape and then rubbed to a smooth face."

makers of bricks from the Gault clays and marls. Analyses of the marls dug at some of these places have been given in Chapter XXIII. Samples of the bricks made at these yards, and of the clay used in making them, are now exhibited in the Economic Department of the Museum of Practical Geology in Jermyn Street. We are also indebted to the managers of these companies for some of the information above given and for the following notes.

The beds exposed in the large brickyard at Burham have been described on p. 89. From a brickmaking point of view they are divisible into the blue clays and the grey marl (known to the company as the "white marl"). The latter is only used for hand-made bricks, and all the machine-made bricks are made from the blue clays alone, which contain from 20 to 31 per cent. of carbonate of lime, known in the trade as "chalk." The bricks always burn white or very pale yellow. The chief output of the works are solid bricks, both ordinary and moulded bricks of various shapes.

The Dunton Green Brickyard is opened in a lower part of the Gault (see p. 90). The manager of the works kindly informs us that for brickmaking purposes the clay dug is of two different kinds, the top portion for a depth of 14 to 30 feet making white bricks, and the lower portion making red bricks. The two portions are separated by a layer of fossils, probably that noted between beds on p. 90. The two clays are kept separate for making into the two kinds of bricks; no chalk is added to either but sand is always used in varying proportions. These works manufacture the following articles: solid bricks, roofing and weathering tiles (pressed and hand-made), ridge tiles, hip and valley tiles, and also pottery ware. All the tiles and pottery are made from the clay which burns red, the lighter clay being only used for bricks.

PHOSPHATIC NODULES (COPROLITES).

Phosphatic nodules occur both in the Gault and in the Greensands at various horizons, from the very base up to the top of the formation.

In the Gault phosphatic nodules occur both in seams or layers, and also scattered through portions of the clay. From the account given of the Kentish Gault (Chapter V.), it will be seen that the Gault of that county is particularly rich in phosphate of lime and that layers of nodules occur at many horizons.

In the Upper Greensand they seldom occur as layers, but are generally scattered through a certain thickness of the sands. In North Dorset however the highest bed of sandstone contains a real nodule bed varying in thickness from six inches to two feet (*see* p. 166).

Most of the nodule beds are of small geographical extent, but some of them have been traced and worked along an outcrop of many miles.

The colour of phosphatic nodules varies considerably, being

sometimes a very pale buff, sometimes brown, and often a very dark grey or nearly black. In the Gault there are frequently both buff coloured and black phosphates, but in the case of the latter the dark tint is external only, the interior being always pale grey or buff. Those which occur in layers are generally black, but sometimes they have lumps of light-coloured phosphate attached to them and sometimes two or more black nodules are partially embedded in light phosphate. In such cases it is probable that the clay in which the black phosphates were formed has been washed away by the action of a current, leaving the nodules to accumulate as a layer, and that a fresh formation of phosphate has subsequently taken place.

In the Greensand, the phosphatic lumps are generally brown, often a bright brown, and in many cases they appear as more or less angular fragments, the original nodule or phosphatised organism having been broken up after its complete consolidation, and before its final embedment in the sand, which now encloses the fragments.

Phosphatic nodules and fragments may be classed under five heads:—

1. Nodules which are evidently internal casts of the shells of Mollusca, or of the tests of Echinoderms, &c.

2. Nodules which seem to have been formed by the accumulation of phosphatic matter in and around a decaying siliceous sponge.

3. Nodules of indeterminate shape, which have probably originated from the decay of soft-bodied organisms.

4. Phosphatic septaria:—apparently lumps of phosphatised mud, which have shrunk in volume during consolidation, leaving a space in the centre from which cracks radiate; such nodules are often brittle, and fly to pieces when tapped.

5. Fragments of shells and of other calcareous bodies, in which the carbonate of lime has been replaced by phosphate of lime.

Phosphatic nodules have been raised in many places, for the purpose of converting them into a soluble superphosphate, to be employed as a manure. There was at one time (from about 1856 to 1880) a great demand for English phosphates, and phosphatic nodules were dug in many places; but the demand stimulated exploration in other countries, and phosphatic deposits of various kinds were found in many parts of the world.

The introduction of foreign phosphates reduced the price of the raw material in England, till at the present time it hardly pays to work the English deposits. Moreover, the easily accessible portions of the best nodule beds have been nearly exhausted, and so long as foreign supplies continue to be abundant it will not pay to follow these deeper nor to work the second-rate nodule-beds which still remain in England. A few pits, however, are still worked near Cambridge.

Phosphatic nodules are commercially known in England as "*coprolites*," a name that came into use from an erroneous supposition that all were the fossilised dung (κόπρος) of extinct animals.

The method of extracting the nodules is as follows: a long trench is dug at one side of the field to be worked, the overlying clay or marl being dug out till the nodule bed is reached; if the depth to be removed is more than 8 or 9 feet, the trench is made in two or three steps or platforms, according to the depth at which the nodule bed occurs. As the nodules are taken out the trench is filled up again with the material removed. The whole thickness of the nodule bed is shovelled into barrows and taken to the washing mill. This is a circular iron trough, with a pivot in the centre to which a set of travelling rakes are attached; a constant stream of water is kept running through the trough, while the rakes are dragged round and round by a horse till all the adherent clay and sand is washed off the nodules. The dirty water having been run off, the nodules are left in the trough and are carted away to be delivered to the manufacturer.

They are then ground to a powder, and this is heated with sulphuric acid to convert the tribasic phosphate of lime into a soluble superphosphate.

The best phosphates are those which contain a large percentage of phosphate of lime, and a small percentage of alumina and of the oxides of iron. Thus, in the case of two kinds of nodules, which on analysis are found to contain about the same proportion of phosphoric acid, that kind will be best for the manufacture of superphosphate which contains the smaller amount of alumina and oxide of iron.

The presence of carbonate of lime, if not in excessive quantity, is rather an advantage than otherwise, and most of the best nodules contain from 10 to 15 per cent. of calcium carbonate. Calcium fluoride, however, which almost always occurs in small quantity (from 1 to 4 per cent.), is disadvantageous, as it wastes acid, and in becoming sulphate of lime its weight increases and it remains as a useless ingredient.

We have collected such analyses of phosphatic nodules from the Gault and Greensand as have been published from time to time. Dr. Voelcker has pointed out that in ordinary commercial analyses the phosphates have generally been precipitated by ammonia, a process which invariably precipitates a certain amount of calcium carbonate at the same time; and further, that all the calcium fluoride present is also precipitated with the phosphates, the result being that the amount of phosphate of lime is stated at 3 or 4 per cent. higher than it really is.[1]

The real amount of the phosphate of lime, says Dr. Voelcker, "can only be correctly estimated by determining the percentage of phosphoric acid, and calculating from this acid the amount of bone-earth" (tribasic phosphate of lime).

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[1] Journ. Roy. Agric. Soc., vol. xxi., p. 357. (1860.)

Lower Gault Nodules.—Phosphatic nodules have been found at or near the base of the Gault in sufficient quantity to pay for working in several parts of the country—at Cheriton, near Folkestone; at Wracclesham and Frensham, near Farnham; at Dinton and Towersey, in Oxfordshire; at Shefford, in Bedfordshire; and near West Dereham, in Norfolk.

At Cheriton the sections showed two beds of nodules, and the two feet of clay between them contained scattered nodules which were picked out by hand. Mr. Topley has described the section (*see* p.) and the method of working them, but no analysis of them seems to have been published.

Dr. J. T. Way, however, analysed two samples from the bed at the base of the *Am. interruptus* zone at Folkestone, and a sample taken from where the bed dipped under the sea gave 25·27 per cent. of phosphoric acid, equal to 52·17 of phosphate of lime. A nodule taken from a mass fallen onto the shore gave a very different composition, consisting mainly of gypsum with some phosphate of iron.[1]

The corresponding bed at Wissant has also been worked and an analysis of a bulk sample of the nodules has been published by M. Berthier,[2] as follows:—

Analysis.		*Composition.*	
Phosphoric acid	24·00	Phosphate of lime -	52·39
Carbonic acid -	4·00	Carbonate of lime -	9·09
Lime -	34·70	Lime in excess	1·22
Oxide of iron	1·30	Oxide of iron	1·30
Pyrites	7·80	Pyrites	7·80
Clay -	19·60	Clay -	19·60
Water, organic matter, and loss	8·60	Water and loss, &c.	8·60
	100·00		100·00

The nodules formerly worked at Wrecclesham and Frensham, on the borders of Surrey and Hants, occur at about the same geological horizon. They have been described by Messrs. Paine and Way, and the section is given on p. 96. Mr. Way analysed a lump of the second phosphatic bed, which is described as a conglomerate of fossils and nodules in a matrix of sand. This lump was broken up, sifted, and the fossils were washed; these fossils, powdered but not dried, gave on analysis:—

Insoluble siliceous matter	43·87
Soluble silica	3·25
Organic matter, water, and fluorine	3·44
Phosphoric acid	20·80
Carbonate of lime -	1·06
Lime in combination with phosphoric acid	23·86
Oxide of iron and alumina	3·35
Magnesia and loss	0·37
	100·00

It will be noticed that the amount of sand and siliceous matter in the above analysis is large; the authors say this might be reduced and the proportion of phosphate of lime increased by a more careful process of sifting, so as to separate the grains of sand from the powder. It is also worthy of notice that the proportion of carbonate of lime is very small. The amount of phosphate of lime shown by the above analysis may be taken as 44·66 per cent.

[1] Journ. Roy. Agric. Soc., vol. ix., p. 81. (1848.)
[2] Annales des Mines, vol. v., p. 208. (1820.)

Messrs. Paine and Way, in 1848, gave the following analysis of a "large Gault fossil from Farnham," presumably a nodule from the main mass of Lower Gault near Farnham :—

Insoluble siliceous matter	·91
Organic matter	2·94
Phosphoric acid	24·28
Carbonic acid -	12·43
Lime	47·46
Magnesia	·21
Oxide of iron -	2·91
Water, fluorine, and loss -	8·86
	100·00

The amount of phosphoric acid in this analysis is equivalent to 53 per cent. of phosphate of lime, and if all the carbonic acid were combined with lime there would be 28·25 per cent. of calcium carbonate.

Prof. J. B. Harrison has carefully analysed a nodule from the Lower Gault of Ridge, in the Vale of Wardour, sent him by myself, and has kindly furnished the following results :—

Analysis.		*Composition.*	
Moisture -	·25	Moisture -	·25
Loss on ignition	3·40	Loss on ignition	3·40
Colloid silica	1·10	Colloid silica	1·10
Clay and quartz -	12·16	Clay and quartz -	12·16
Iron peroxide and alumina	4·44	Iron peroxide and alumina	4·44
Iron protoxide	3·74	Ferrous carbonate	6·03
Calcium oxide	39·12	Calcium carbonate -	19·38
Magnesium oxide -	·54	Magnesium carbonate - -	1·13
Carbonic anhydride	11·41	Calcium sulphate	·83
Sulphuric anhydride	·53	Calcium phosphate -	51·60
Phosphoric anhydride -	23·64		
	100·33		100·32

Upper Gault Nodules.—Phosphatic nodules occurring in Upper Gault have only been worked in one part of England, namely, between Puttenham in Bucks, and Stanbridge in Bedfordshire. The following analyses of them have been published, the first being a sample analysed by Mr. Bernard Dyer, the second by Mr. Alfred Sibson.

	I.	II.
Moisture -	?	·68
Lime -	46·76	46·11
Phosphoric acid	27·41	30·04
Alumina - -	1·95	17·04
Oxide of iron -	1·40	
Carbonic and sulphuric acids	17·93	
Insoluble siliceous matter	4·55	6·13
	100·00	100·00

Mr. Dyer states that the rough sample contained ·52 of moisture and 59·53 of tribasic phosphate of lime. The amount of phosphoric acid in his analysis is equivalent to 59·85 per cent. of the phosphate. The analyses by Mr. Sibson shows a very high percentage of phosphoric

acid, and probably includes some calcium fluoride, which is precipitated with the phosphate unless care is taken to prevent it.[1]

The following are partial analyses of the nodules formerly raised from a seam about 20 feet above the base of the Gault near Shefford, in Bedfordshire (*see* p. 285). The first was made by Dr. Voelcker, the second by Mr. Bernard Dyer; and both were communicated to me many years ago by Sir J. B. Lawes, of St. Albans.

	I.	II.
Moisture and organic matter	3·79	5·85
Lime	46·13	44·44
Phosphoric acid	27·68	27·27
Carbonic acid, sulphuric acid, oxide of iron alumina, magnesia, &c.	17·76	16·01
Insoluble siliceous matter	4·64	6·43
	100·00	100·00

The amount of phosphoric acid in the first analysis is equivalent to 60·42 per cent. of bone-earth phosphate of lime, and that of the second to 59·53 of phosphate of lime. As the carbonic acid was not separately estimated, the amount of carbonate of lime cannot be calculated, but there is probably about 24 or 25 per cent. in each case.

Cambridge "Coprolites."—These may be mentioned here, for although they now occur in a bed at the base of the Chalk Marl, they are really nodules derived from the Upper Gault, and must be regarded as having been formed originally in the Gault, and not in the Chalk Marl,

Dr. A. Voelcker analysed three samples of these nodules in a very complete manner and published the results in 1860,[2] these being as follows:—

——	No. 1.	No. 2.	No. 3.
Moisture and organic matter	4·63	4·01	3·52
†Phosphoric acid	25·29	26·75	27·01
Carbonic acid	6·66	5·13	5·49
Sulphuric acid	·76	1·06	Not determin'd.
Chloride of sodium	·09	traces.	traces.
Lime	43·21	45·39	46·40
Magnesia	1·12	·48	1·06
Oxide of iron	2·46	1·87	2·08
Alumina	1·36	2·57	1·41
Potash	·32	·84	Not determin'd.
Soda	·50	·73	
Insoluble siliceous matter	8·64	6·22	6·04
Fluorine and loss	4·96	4·95	6·79
	100·00	100·00	100·00
†Equal to tribasic phosphate of lime	54·89	57·12	58·52

[1] *See* Dr. Voelcker in Journ. Roy. Agric. Soc., vol. xxi. p. 358. He says the amount of calcium fluoride is often 3 or 4 per cent.

[2] Journ. Roy. Agric. Soc., vol. xxi. p. 358. (1860.)

Dr. Voelcker also gives the several amounts of carbonate of lime on the assumption that all the carbonic acid is combined with lime, but it is probable that the magnesia is also in the state of a carbonate. It is impossible to say exactly how all the elements are combined in the original nodule, but there is always a slight excess of lime beyond that required to combine with the acids to form phosphate carbonate and sulphate of lime, and with the fluorine to form fluoride of calcium. It is probable that this excess of lime, with the iron and alumina, is derived from the partial decomposition of a silicate, such as glauconite, by the action of the hydrochloric acid used as a solvent in making the analysis.

On the suppositions above mentioned the composition of the nodules analysed may be stated as follows, omitting the chloride of sodium, which was only estimated in one of them :—

	No. 1.	No. 2.	No. 3.
Moisture and organic matter -	4·63	4·01	3·52
Phosphate of lime (3 CaO, P_2O_5)	55·21	58·39	58·96
Carbonate of lime	12·25	10·47	9·94
Sulphate of lime - -	1·29	1·80	—
*Fluoride of calcium -	4·00	3·00	2·20
Carbonate of magnesia	2·35	1·00	2·22
{ Excess of lime - - -	3·89	5·61	8·01
{ Oxide of iron and alumina	3·82	4·44	3·49
{ Potash and soda -	·82	1.57	—
Insoluble matter - -	8·64	6·22	6·04
Loss -	3·01	2·54	5·72
	99·61	99.05	100·10

If the Magnesia is present as a phosphate, the total amount of phosphates will be slightly less and the excess of lime will be a little greater: the proportion of carbonate of lime will also be greater, but the total of carbonates nearly the same.

Road Metal.

The "Greensand" part of the formation contains many beds of stone, which have been used for road-metal, some of them continuous layers, and some being layers of large isolated doggers, or "burr-stones," as they are called in Wiltshire. The cherts, locally known as flints, which they much resemble, are also used in most of the districts where they occur.

The continuous beds of calcareous sandstone are often termed "ragstone" by the workmen. Such beds occur and have been used for this purpose in Hampshire (*see* p. 104); in Wiltshire (*see* pp. 241 and 251); in the Isle of Wight (*see* p. 135); and in North and West Dorset (*see* pp. 162 and 171).

The Chert beds have been worked for road-metal in Wiltshire, near Warminster, Sutton-Veny, Longbridge Deverill, and Maiden Bradley. In the Isle of Wight they have been dug on St. Catherine's Down, near Ventnor, at Shorwell, Gatcombe and Whitcombe. They have been also dug in parts of West Dorset and at many places in East Devon, where the layers of

* The amounts of fluoride of calcium are taken from a paper by Mr. W. C. Reid in the "Chemical News," vol. 34, p. 48 (1876), where these analyses are referred to, but are not given in full.

chert are very numerous and have often settled and slipped down into tracts of chert gravel.

In many places, too, cherts are picked off the surface of the fields and carted thence to the road without the trouble of quarrying.

Cherts, when broken small enough, make a good road for winter wear and for so long as they are kept wet by rain, but they break up into dust and sharp chips of stone in dry weather, and the road then becomes loose and bad, especially for rubber tyres. The surface lasts better if they are mixed with ragstone or some hard kind of limestone.

Scythe Stones.

We know of only two places where stones for sharpening scythes have been obtained from the Greensand; the first is the Blackdown Hills of Devonshire, north-west of Honiton, and near Kentisbeare; the second is west of Mere on the borders of Somerset and Wiltshire.

The Blackdown beds were largely worked at the beginning of the century, but the demand has fallen off so largely that at the present time only one family carries on the work and only one mine or tunnel is open.

The beds which yield the siliceous concretions, from which the whetstones are made, have been described on page 214, and the following account of the industry is quoted from that given by Dr. Fitton in 1836[1] :—

"The total thickness of the strata which furnish the material for sithe-stones, including the rejected sand and rubbish, is from 12 to 18 feet; the whole of which is removed in cutting the drifts or galleries. . . . These are driven in direct lines into the hill, almost horizontally, and in some cases for considerable distances. The stony masses from which the sithe-stones are cut are concretions of very irregular figure, embedded in looser sand . . . they vary from 6 to about 18 inches in diameter.

"When first taken out the stone is greenish and moist and can be cut or chopped with ease. The tools employed are a sort of axe or adze with a short handle, called a 'basing-hammer,' which is ground to a sharp edge. .

"For the purpose of cutting the stones a vertical post of wood or 'anvil' is so fixed in the ground as to stand between the knees of the workman, who sits upon a sort of bench built of stone, with some strong pieces of old leather as a defence to his left knee. He first with the edge of his basing-hammer splits from the blocks upon his knee long portions approaching to the shape of the sithe-stones, and then cuts or chops them down nearly to the required size upon the anvil and his knee—just as a carpenter cuts timber with an adze. After being thus rudely shaped, the stones are hewn to the proper dimensions with a large hammer, and then rubbed down with water by women on a large stone of the same kind; when dried they are fit for sale.

"The stones when finished vary from about ten to twelve inches in length; some have the shape of a portion of an almond, with the ends and sides cut square, and about 2 inches by 1½ in thickness; others are almost cylindrical, but smaller at each end, with the sides a little curved, the diameter in the middle about 2 inches. A good workman can cut out of the blocks about seven dozen of the stones per day."

Dr. G. J. Hinde describes the material of the concretions as "porous, very harsh to the feel, partly hard and partly soft and friable. It is filled with

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[1] Trans. Geol. Soc., Ser. 2, vol. iv. p. 236.

sponge-spicules and their empty casts cemented together by chalcedonic silica. Quartz sand and glauconite grains are also present, but no calcite, and only a small amount of mica."[1]

Water Supply.

Where the Selbornian group consists largely of sand or of malmstone, it often yields a copious supply of good water Along a gentle scarp where these beds are underlain by the Gault clays and marls much of the water is thrown out at the surface in the form of springs, while the rest of it passes inward along the subterranean extension of the beds.

The quantity of water, however, which finds its way into the Greensand depends mainly on two conditions: (1) the breadth of the outcrop or basset surface, (2) the marliness of the lower part of the overlying Chalk. Where the beds are steeply inclined the breadth of the basset surface is small, and consequently the amount of water absorbed by it is also comparatively small. Again, where the overlying chalk is very marly, the water which passes down through the mass of the Chalk does not reach the Greensand, but is held up by the Chalk Marl, and part of it issues in a separate set of springs. Where, however, the Chalk Marl contains little argillaceous matter, as in parts of Wiltshire, or where it is traversed by many fissures, some of the Chalk water seems to get through to the Greensand and swells the volume of the springs which are thrown out by the Gault.

Along the northern border of the Wealden area the conditions do not favour the absorption of water by the Upper Greensand; for the outcrop is narrow and the overlying Chalk Marl is decidedly argillaceous. As a consequence the springs issuing from the sandy beds are feeble, and so little water finds its way along their underground extension that few borings in the London Basin derive any supply from this formation.

There is indeed only one boring in London which has obtained any considerable supply from this source, and that was made in 1879 at the Albion Brewery, Mile End (Messrs. Mann, Crossman & Co.). The following is condensed from the published account[2]:—

——	Thickness.	Depth.
	Feet.	*Feet.*
Surface Deposits - -	20½	20½
London Clay - - - -	84½	105
Woolwich and Reading Beds	41	146
Thanet Sand - -	55	201
Upper Chalk and Chalk Rock	259	460
Middle Chalk - - -	200	660
Lower Chalk - - -	195	855
Upper Greensand - -	20	875

[1] "On Beds of Sponge Remains," Phil. Trans. Roy. Soc. (1885,) p. 421.

[2] J. Barrow, "Proc. S. Wales Inst. Eng.," vol. xi. p. 326, and W. Whitaker, "Geology of London," vol. ii. (Mem. Geol. Survey, p. 134).

The water rose from the bottom of the bore to within 105 feet of the surface, and by continuous pumping over 500,000 gallons a week were lifted. As other wells in Mile End have found a plentiful supply of water about 200 feet below the top of the Chalk, it may be that below the Albion Brewery there are fissures in the Chalk by means of which the Chalk water is carried down to the level of the Upper Greensand, and that the supply is not really derived from the latter formation.

Returning to the surface outcrop, it is noticeable that in the east of Hampshire this occupies a much wider tract of ground, and consequently takes up a much larger quantity of water. Some of this is thrown out in the form of springs at or near the base of the Malmstone, and some must find its way westward beneath the Chalk. The villages on the outcrop of the Malmstone find a good supply of water by sinking wells into that rock, many of them being from 60 to 80 feet deep. The water, however, is somewhat hard.

In West Sussex the conditions are similar, but in proceeding eastward the thickness of the Malmstone and sandy beds becomes less and less, the width of their outcrop becomes correspondingly less, and in East Sussex the springs issuing from them appear to be feeble[1].

Along the main line of outcrop through the counties of Bucks, Oxford, Berks, Wilts, and Dorset a larger amount of water finds its way into the Malmstone and Greensand, especially where these beds form a terrace in front of the Chalk Hills, with a minor escarpment of their own. Many copious springs issue from the outer slope of this tract; thus, in Oxfordshire there are fine spring-heads at Postcombe, Adwell, Easington, Cadwell, and Berwick Prior.

In Berkshire, on the western side of the Thames valley, the Malmstone forms a semicircular ridge of high ground to the west and north-west of Wallingford. Strong springs are thrown out on the inner side of this ridge at Satwell and Brightwell, but a considerable amount of water must find its way southwards and south-eastwards beneath the chalk. In Wallingford itself a plentiful supply is obtained from this source, as, for instance, at the Anchor Brewery, where a boring made by Messrs. Legrand and Sutcliff traversed the following beds:—

	Feet.
River gravel and sand	22
Blue clay [? Chalk Marl]	24
Alternating beds of soft sandstone and greensand	4½
Grey Marl	½
	51

Another well (at Mr. Hilliard's brewery) got water from light-coloured sand at a depth of 40 feet.

[1] See "The Water Supply of Sussex," Mem. Geol. Surv., by W. Whitaker and C. Reid, 1898.

Of the Wallingford Waterworks the following account has been published.[1] They are situated in a field south-west of the town and adjoining the railway-station on the west side. The boring was completed in 1884, and the water rose to within a few feet of the surface and was pumped at the rate of 6,000 gallons an hour for 70 hours without making any appreciable effect on the head of water. The beds traversed were as follows:—

		Ft.	In.
Sand and Gravel		13	0
Chalk Marl	Soft sandstone	3	0
	Hard sandstone	6	6
	Blue clay	2	0
	Alternate beds of soft blue stone and blue clay	21	6
Upper Greensand	Hard blue stone	7	4
	Sandy clay	1	11
		55	3

A later note from Messrs. Legrand and Sutcliff, who made the boring, states that the estimated yield by lowering the water 25 feet is 9,600 gallons per hour.

A boring made by the same firm at the Moulsford Asylum about 2¼ miles south of the above site confirms the reading of the beds traversed. This was carried to a greater depth, and the particulars furnished are as follows:—

	Ft.	In.
River gravel	13	0
Grey rock chalk	33	0
Greensand	9	6
Hard grey sandstone	6	8
Ditto, with layers of clay	18	10
	81	0

The yield from this boring was 15,000 gallons an hour. From these facts one may infer that the Upper Greensand should furnish a good supply of water for some distance further south, if it were ever found necessary to seek it.

Passing westward through Berkshire, there are springs from the base of the Malmstone at Didcot, Harwell and near Steventon, but thence as far as Wantage the springs at this horizon are weak and the surface water-supply comes mainly from the Lower Chalk. At the same time the Malmstone forms a well-marked terrace in front of the chalk escarpment, and places situate upon it find a fair supply of water by sinking wells. Thus, the Wantage Brewery Company obtain their supply from the sandy marls at the base of the Malmstone. The boring made here in 1884 traversed the Gault and Kimeridge clay and obtained water from the Corallian beds, but the water so obtained did not prove satisfactory for brewing purposes. I am indebted to Mr. G. Martin, the manager of the company, for the information that in August, 1898, they sank a new shaft to a depth of 32 feet, and from it drove

[1] "Engineer," vol. lxi. pp. 120, 121. (1886.)

two tunnels through the sandy marl, going 80 feet in one direction and 20 feet in an opposite one; they met with several good springs, and by this means obtained a sufficient supply of suitable water without going to a greater depth.

Further west, though the outcrop of the Malmstone becomes narrower, many fine springs issue from it in the western part of Berkshire and the northern part of Wiltshire. Possibly this copious supply is due to the fact that in this district the Lower Chalk contains so little argillaceous matter that much of the chalk water finds its way down to the Malmstone. In Berkshire the most notable spring-heads are at Sparsholt, Kingston Lisle, Bridgecombe, Woolstone, Ashbury and Bishopstone. In North Wilts springs from this source occur at Wroughton (supplying Swindon Water-works), Cliffe-Pypard (supplying Wootton Basset), and at Highway.

Devizes was formerly supplied with water from open wells sunk through the sand and sandstone on which the town stands, but as the old system of drainage was by cess-pits, and as the sandstone is traversed by many joints and fissures, the condition of the water-supply naturally became very bad, especially in the older parts of the town. The present waterworks, obtaining a supply from the Chalk at some distance to the north-east of the town, were established about 20 years ago.

It is worthy of remark that the water now supplied to Devizes from the Chalk is not so hard as the water formerly obtained from the Greensand. This is probably to be explained by the difference of the surface soils; that near Devizes is a deep vegetable earth, often black and peaty, and highly cultivated, so that the water passing through it takes up much carbonic acid, while the soil on the Chalk is thin and only supports a short herbage. The amount of lime which water can hold in solution as carbonate depends on the amount of carbonic acid which it takes up on its way through the air and soil, and a water containing much carbonic acid would dissolve out more lime from the calcareous beds in the Greensand than the less carbonated water entering the Chalk could extract from that formation.

South and south-east of Devizes strong springs issue from the middle of the Greensand at Drew's Pond, Potterne and Urchfont, and also from the higher sands at Nurstead and Stert. Eastward again beneath the Vale of Pewsey the Greensand occupies a wide surface-area and is saturated with water; the numerous springs issuing from it, as well as from the Lower Chalk, form the head-waters of the River Avon; while the villages on the Greensand are supplied by shallow wells sunk into the sand.

The Vale of Warminster is another tract where the Selbornian Sands occupy a considerable surface-area, and where as a consequence they hold a large quantity of water. The ridge of Greensand which forms the western border of this tract is part of the watershed separating the head-waters of the Wily from the streams which run into the River Frome. On the western side

of this ridge there are numerous springs issuing from the Malmstone and forming feeders of the Frome. On its eastern slope towards Crockerton and Warminster are springs which contribute largely to the head-waters of the Wily.

In Warminster town a plentiful supply of water is found by sinking through sand and one bed of calcareous sandstone, water coming in from below the latter at depths of from 25 to 30 feet. At Heytesbury also, which stands on the Chalk Marl, the wells traverse this marl and find water in the sand below.

From the southern border of the Vale of Warminster the outcrop of the Greensand is continued as a high plateau or terrace by Maiden Bradley and Stourton, terminating on the west in a very steep slope; and on this slope strong springs are thrown out at frequent intervals along its line of passage into the Gault clays. On the plateau good water is obtained from wells sunk through the sands to a depth varying from 60 to 120 feet.

The southern end of this plateau, near Stourton, is trenched by several deep valleys formed by the head-waters of the River Stour, each valley having a strong spring at its upper end, the most copious being known as Stourhead.

In the Vale of Wardour the influence of tectonic position on water-bearing beds is well exemplified, both the total amount of water taken up, and the amount which issues in springs, depending very greatly on the amount of inclination of the beds.

A reference to the section across this valley given on p. 229, and to the account in Chapter XVI., will remind the reader that on the northern side of the anticline the beds dip steeply to the north, while on the southern side the dip is very slight, and the beds seem in places to be nearly horizontal.

On the northern side the outcrop of the Greensand forms a narrow ridge, and very little water is thrown out at its base, whereas copious springs issue from the Chalk behind this ridge, which is trenched by the watercourses proceeding therefrom. The features of the southern side of the Vale are very different; no springs issue from the Chalk above the Greensand; the outcrop of the latter forms a continuous plateau or terrace, indented only by valleys formed by the issue of strong springs from the lower beds of the Greensand. The villages on this terrace are of course supplied by wells dug through the sand.

The country round Shaftesbury presents a continuation of the conditions prevailing along the south side of the Vale of Wardour. Shaftesbury itself is supplied with water from the Upper Greensand formation on which it stands; the waterworks are to the east of the town, and Mr. W. Hill was informed in 1897 that the well there was 140 feet deep, the water coming in from sandstone (? malmstone) near the bottom.

In Dorset, as one proceeds southwards from Shaftesbury, the outcrop of the Greensand sinks in that direction from a height of 600 feet to one of little over 200 feet and as a consequence the springs rise from higher and higher horizons. Near Melbury and Compton Basset the water issues in strong springs from the

base of the malmstone; south of Compton it rises high up in the sands, and again in Iwerne Minster Park there are springs rising in the midst of the sands, the water from some flowing southward to form the Iwerne brook, and from others north-westward to join the Fontmell brook, but very little issues from the base of the sands in that neighbourhood.

From the valley of the Stour, however, the Cretaceous escarpment trends westward, and once more strong springs are thrown out from the Upper Greensand by Okeford Fitzpaine, Belchalwell, Ibberton and Woolland, and thence also at frequent intervals all along the boundary of this subdivision throughout northern and western Dorsetshire. Moreover certain streams which flow southward through the Chalk hills take their rise in springs which issue from the Greensand close to the ridge of the main escarpment. The Dewlish water indeed rises on the outer or northern side of this escarpment, being fed from springs at Melcombe and Anstey. The Cerne derives its most northerly affluent from springs at Minterne, and the Dorset Frome has three main branches all of which receive most of their water from the Greensand; one of these rises at Evershot, the second near Rampisham, and the third collects the waters of many springs near Hooke, west of Maiden Newton.

Springs issuing from the Upper Greensand at Litton Cheney furnish the water-supply for the town of Bridport.

The south-eastern part of Devonshire, with the adjacent portions of Dorset and Somerset, from Chard and Axminster to the valley of the Otter, and from the Blackdown Hills on the north to the sea-coast on the south, is a land of springs and streams, almost all of them deriving their water from the Upper Greensand. This region was once a plateau, but is now cut up into a varied succession of narrow ridges capped by a dry and flinty soil, divided from each other by deep vales from which the freshness of running water is never absent. The major valleys branch into minor valleys, and these into little combes, each of which has its spring or springs, and few of them ever run dry. Much larger towns than Axminster or Honiton might be supplied with the excellent water furnished by these springs, and much more use might be made of the water-power which the streams afford in their rapid transit from their sources to the sea.

APPENDIX—PALÆONTOLOGY.

A.—CRITICAL REMARKS ON SOME SPECIES OF FOSSILS.

By E. T. NEWTON, F.R.S., and A. J. JUKES-BROWNE.

THE fossils of the Upper Cretaceous Series have not been studied so thoroughly as those of most other British formations, and in many respects our knowledge of Cretaceous fossils is behind that of French and German palæontologists. Monographs dealing with certain groups have indeed been published: namely, on the Sponges by Dr. Hinde, on the Corals by Duncan, on the Echinoderms by Wright and on the Brachiopods by Davidson; but on the large and important classes of the Lamellibranchiata and the Gastropoda no complete monographs have yet appeared. It is true that a few genera and families belonging to these classes have been separately studied, such as *Trigonia* by Lycett, *Nucula* and *Leda* by J. S. Gardner, who has also dealt with the Cretaceous species of the *Aporrhaidæ, Dentalidæ, Patellidæ,* and *Fissurellidæ.* The useful work thus done serves to make it still more apparent how very much remains to be done on the fossils belonging to these classes.

The Cretaceous Cephalopoda were partly described and figured by Sharpe in 1849, but his work requires revision, and the Cephalopods of the Gault and Greensand have never yet been monographed in English. It is true that a catalogue of the Fossil Cephalopoda in the British Museum is in course of publication, and that a monograph on the Cretaceous Lamellibranchs has been undertaken by Mr. H. Woods for the Palæontographical Society, but these have not yet proceeded far enough to help us much.

There are among Cretaceous fossils a large number which have not yet been figured in any English work and for the determination of which one must consult the works of French and German palæontologists. There are also many questions of synonomy which can only be properly settled by comparisons with British and foreign types.

During the preparation of the lists of fossils for this work, and of the general catalogue which follows, these questions have been discussed between Messrs. Sharman and Newton and myself, in order that we might decide under what name certain species should be entered. This being so, it has seemed to us desirable to insert notes on the identification and synonomy of some of these species, so that other workers may know exactly what forms are indicated by the names used in this volume.

AMMONITES [ACANTHOCERAS] BROTTIANUS, *d'Orb.*, var. SEXANGULATUS, *Seeley.*

1841. Am. brottianus, *d'Orb.* Pal. Fr. Terr. Cret., tom. 1, p. 290, pl. 85, figs. 8-10.

1847. Am. brottianus, *Pictet.* Grès Verts de Genève. Cephalopodes, p. 85, pl. 7, figs 9-11 (var. 11).

1865. Am. sexangulatus, *Seeley.* Ann. Mag. Nat. Hist., ser. 3, vol. xvi. p. 233, pl. xi. fig. 1.

This species is only at present known in England as a rare fossil in the Cambridge Greensand. Mr. Seeley correctly distinguishes his *A. sexangulatus* from *A. itierianus*, but merely adds, "*A. brottianus* is nearly related." The points in which it differs from the type of *A. brottianus* are (1) the curvature of the ribs, (2) the compression of the shell and consequent flatness of the sides, (3) the smaller umbilicus. But Mons. Pictet remarks, "when this ammonite is young it often happens that the ribs are less straight and that they form a slight double curvature, being bent forward toward the umbilicus and recurved toward the back. This form shows itself especially in some compressed individuals which occur both at the Perte du Rhône and at Saxonet, and which appear to form a constant variety (depending perhaps on sex?), but which has, however, too much resemblance to the others to be regarded as a distinct species."

A compressed *A. brottianus* with slightly curved ribs must approach very closely to the *sexangulatus* of Seeley, and much variation in the size of the umbilicus by a greater or less enveloping of the whorls is seen in other species, such as *A. Mantelli*, *A. sexangulatus* is probably related to *A. brottianus*, much as *A. Mantelli* to *A. navicularis* and *A. varians* to *A. Coupei.*

AMMONITES [DESMOCERAS] BEUDANTI, *Brong.*

1822. Am. Beudanti, *Brong.*, Env. de Paris, Cuvier, Ossem. Foss., Vol. ii., part 2, pl. 7, fig. 2.

1829. Am. lævigatus, *Sow.*, Min. Con. pl. 549.
Am. Beudanti, *d'Orb.*, Pal. Fr. Terr. Cret.

The present resting-place of the specimen from Crockerton, Wilts, figured by Sowerby (*loc. cit.*) as *A. lævigatus* is not known; but one or two examples of the same species, mentioned by Sowerby as from Cheriton, near Folkestone, are in the Sowerby collection at the British Museum. Having examined them, we are convinced that the *A. lævigatus* of Sowerby (above referred to) is the same species as the form from the Gault, which for years has been known as *A. Beudanti*; and further, there seems to be no reasonable doubt that these Gault *Ammonites* are the *A. Beudanti* of Brongniart and of d'Orbigny. The name *A. Beudanti* will therefore continue to be used for this Gault Ammonite, which, it seems, occurs both in the middle and lower parts of the Gault, but has not been found in the *A. mammil-*

latus beds at the base of the Gault, this bed yielding another form, to be mentioned below.

Most of the specimens available for examination have the simple and distinct lobe line shown by the figures of d'Orbigny and Sowerby; but in some specimens, especially (but not exclusively) the larger ones, the processes become more developed and consequently interdigitate to such an extent as to make them difficult to trace. At present there is not sufficient evidence to prove that this form with the complex lobe line is a distinct species.

An Ammonite which cannot be separated from the true *A. Beudanti* occurs in the Upper Greensand of Blackdown, and is represented by a specimen in the Museum of Practical Geology; but as the lobe line is not shown in this specimen the species is uncertain.

In the *A. mammillatus* bed at Folkestone, which has sometimes been thought to be the uppermost bed of the Lower Greensand, an Ammonite is commonly met with which has been called *A. Beudanti;* it has much the same form as that species, but, besides having a complex lobe line, even in the smaller specimens, always shows a series of ligations, and for this reason has been thought by some to be most closely related to *A. planulatus;* but the last-named species has an open umbilicus with narrower and more inflated whorls.

Pictet and Campiche (Terr. Cret., St. Croix, 1858-60, p. 277) include certain ligated forms in *A. Beudanti;* but seeing that in our experience the ligated form with complex lobe line is not met with in the Gault itself, we think it will be wise to keep this form distinct, at least for the present, and it may be called the variety *ligatus.*

Am. Beudanti var. ligatus has long been known to occur in the *A. mammillatus* beds at Folkestone, and Mr. G. W. Lamplugh has recently collected characteristic examples from the same horizon at this and other localities. Mr. Clement Reid also found this variety several years ago, at West Dereham in Norfolk, in beds apparently occupying a similar horizon between the Upper and Lower Cretaceous strata. A fragment of this same ligated Ammonite was obtained by Mr. W. Whitaker from a well-boring, near Ashford, Kent, accompanied by a piece of *Am. mammillatus.*

Ammonites bicurvatus d'Orb. has a very similar form to *A. Beudanti,* but its lobe line is different, and this has caused it to be placed with *Placenticeras* and not with *Desmoceras.* The species has not been recognised in Britain.

AMMONITES [HOPLITES] AURITUS, *Sow.*, VAR. CATILLUS, *Sow.*

Ammonites catillus, Sow., is a species about which much doubt has existed. It has never been examined or discussed by any English writer since Sowerby's time, and the form figured

by d'Orbigny under the name of *A. catillus* differs so much from that of Sowerby that it can hardly be the same species.

The following is Sowerby's description: "A very flat species with only three or four whorls; the surface of it is even, except a row of short tubercles on each side the margin, which degenerate into obscure waves upon the outer whorl. It might possibly be taken for a compressed specimen of *A. varians*, but it wants both the carina and radii. . . . . It is above six inches wide, and only nine-tenths of an inch thick." The figure given by Sowerby (Min. Con. tab. 564, fig. 2) is not good, but shows a set of obscure tubercles round the umbilical margin of the whorls, while the back is smooth and rounded. The specimen was obtained from the malm-rock in a quarry at Nursted, near Petersfield.

The figure given by d'Orbigny (Pal. Franc. Pl. 97, f. 1-2) shows an Ammonite of about the same size with obscure ribs which end in broad flat projections which can hardly be called tubercles. These projections form a regular row along each side of the back, leaving a flattish depressed area between them. It thus differs materially from Sowerby's type.

In 1881[1] Mr. C. Parkinson briefly described an Ammonite which is not uncommon in the lower part of the Upper Greensand. He says, "It is invariably of the same size, from 2½ to 3 inches in diameter, and remarkably thin for its size, not having the prominent tubercles of *A. auritus* or the sharply defined chambers of *A. rostratus*. At the back the markings are alternate, more resembling the Gault species *A. interruptus*." He adds that neither Mr. Etheridge nor Dr. Wright, to whom he had shown specimens, could identify them with any species known to them. In Mr. M. Norman's "Geological Guide to the Isle of Wight" (1887), opp. p. 76, there is a fairly good figure of an Ammonite (unnamed) which agrees with the above description and is probably meant to represent the form described by Mr. Parkinson, but no special mention was made of it. It has the aspect of a flat and obscurely marked *A. auritus*, and is not unlike the figure and description of *A. catillus*, except that it has low dorsal tubercles.

In 1898 Dr. W. Curtis, of Alton, Hants, was kind enough to send us most of the fossils obtained by his father from the Malmstone of Hampshire, and among them were two Ammonites with flat sides and rounded backs, but with umbilical tubercles and faint ribs like those of *A. auritus*. They so nearly resemble the *A. catillus* of Sowerby that we had no hesitation in regarding them as referable to that species, especially as they come from the same formation as the type specimen; but at the same time it appeared to us that they were only an extreme form of *A. auritus*.

The next step was evidently to examine Sowerby's type specimen in the British Museum. The figured type of J. C. Sowerby (from Nursted) is a very indefinite specimen, but

[1] Quart. Jour. Geol. Soc., vol. xxxvii, p. 371.

it and others have tubercles round the umbilicus and indefinite swellings along the back; these forms do not show any trace of the two ribs running into a tubercle on the back as in *A. auritus.* A specimen from Hampshire (in the Alton Museum), however, does show traces of two such ribs.

There are many specimens of *Ammonites auritus* from the Malmstone and Upper Greensand which show variations approaching to *Am. catillus.* Some are strongly and others finely marked, but in both varieties the last whorl often becomes nearly smooth on the sides The coarser variety generally shows tubercles along the back, but the more finely marked lose their dorsal tubercles and are evenly rounded over the back."

The relations of all these forms are such that we prefer to regard *A. catillus* as a variety of *A. auritus,* and in this opinion Mr. G. C. Crick agrees."

The variety *catillus* is found in the Malmstone of Oxfordshire and of Buckinghamshire, and we think there can be little doubt that it also occurs in the Isle of Wight. The flatness exhibited by so many specimens is evidently in most cases due to compression after embedment, and is not an original character.

AMMONITES [HOPLITES] DISPAR, *d'Orb.*

1840–41. Am. dispar, *d'Orb.*, Pal. Fr. Terr. Cret., vol. i. p. 142.

1858–60. Am. dispar, *Pict. & Camp.*, Terr. St. Croix., part. i. p. 264.

1865. ? Am. navicularis var. nothus, *Seeley.* Annals and Mag. Nat. Hist., vol. xvi. p. 232.

A number of specimens, which are referred to the above species, have been collected by Mr. Rhodes for the Geological Survey, from the uppermost bed of the Upper Greensand of North Dorset; and other examples of the same form and from the same horizon are in the Dorchester Museum.

These specimens agree so closely with the descriptions and figures given by Pictet and Campiche (especially pl. 38, figs. 1. 2, 5,) that there is no doubt as to their belonging to one and the same species. There is the same small umbilicus, nearly straight ribs, passing regularly over the rounded back, the same absence of ribs from the outer whorls of the adult, presence of small tubercles on each side of the back in the young stages, and less distinctness of the ribs across the back between the pairs of tubercles;—in all these characters there is the closest agreement.

The original figures given by d'Orbigny appear at first sight so unlike those of Pictet and Campiche as to raise a doubt as to their being the same species. The suture line is especially unlike; but d'Orbigny states that he is uncertain in this particular. Again, his reference of this form to the Neocomian raises another doubt, but this seems to have been an error, which he rectified in the "Prodrome," vol. ii. p. 146, where this species, put as synomyn of *A. catillus,* is included in the list of Cenomanian species.

Messrs. Pictet and Campiche, however, state that they examined d'Orbigny's original specimen, and express themselves as quite satisfied as to the specific identity of their fossils with the type of *Am. dispar.* The species is undoubtedly a variable one, as shown by the figures of the Saint Croix specimens. The depressions or grooves upon the sides of the type, which seem so distinctive, have their counterpart in one at least of the St. Croix examples, and may be seen in one of the Dorset specimens.

The two forms from the Cambridge Greensand named by Professor Seeley *Am. navicularis* var. *notus* and *Am. rhamnonotus* are undoubtedly closely allied forms; for their suture lines seem to be identical with those of the species above noted, and the variety *Am. navicularis notus* will almost certainly have to become a synonym of *Am. dispar.*

Am. rhamnonotus has a row of tubercles along the middle of the back and the ribs are bent a little forward, characters which are not seen in any example of *A. dispar.* The close resemblance in other particulars, even to the small tubercles on each side of the back, between this Ammonite and the Dorset specimens led one of us to refer the latter to *A. rhamnonotus* in 1893, (Proc. Dorset Nat. Hist. and Antiquarian Field Club, vol. xvii., p. 104), but the examination more recently of the inner whorls of young Dorset specimens has shown that there are no median tubercles, and by the kindness of Prof. T. McK. Hughes comparison has been made with Prof. Seeley's types in the Woodwardian Museum, Cambridge.

The doubt respecting the identity of the forms which had been called *Am. dispar* having also been cleared up, we think that the Dorset species must be referred to the *Am. dispar* of Pictet and Campiche, and we accept the dictum of those gentlemen that their specimens belong to d'Orbigny's species, they having compared the types.

ACTÆON AFFINIS, *Sow*, AND ITS CONGENERS.

1826. Actæon affinis, *Sow.*, in Fitton, Trans. Geol. Soc., ser. ii., vol. iv.

1834. Ringinella lacryma, *d'Orb.*, Mich. Mag. de Zoologie, cl. 5, pl. 33, and Pal. Franc. III. pl. 167, figs. 12, 21–23.

1842–3. Actæon Vibrayeana, *d'Orb*, Pal. Fr. III. pl. 167, figs. 16–18.
Actæon (? new species, Blackdown).

In 1897 Mr. C. J. A. Meyer called our attention to the fact that the shells from Blackdown, which have hitherto passed under the name of *Actæon affinis*, included two different forms or varieties, of which he was kind enough to send us specimens. On examining these, none of them agreed well with Sowerby's figure of *A. affinis.* One form had the general shape of *affinis*, but was rather more inflated, with a sharp outer lip and three distinct teeth or spiral plates on the columella. This comes nearer to *Actæon vibrayeana* than to any other species, but

may be a new form. The other specimens are more elongate, and closely resemble the *Ringinella lacryma* of d'Orbigny, having three plaits, two large and thick and one smaller.

Most of the specimens in the Museum of Practical Geology agree in shape with Sowerby's figure of *A. affinis*. The teeth are three in number, but one is small, and they are placed close together near the spout. Sowerby describes *affinis* as having 'two teeth, one double.'

There are also two elongate specimens with teeth like *A. affinis*. The markings on these vary from simple punctuations to elongate pits. They resemble the *Ringinella lacryma* of d'Orbigny, but we do not think that this form belongs to a different genus. It might be called *Actæon affinis*, var. *lacryma*.

There are also two specimens in the Museum like Mr. Meyer's inflated form, with three large separate teeth; these appear to be another variety, or perhaps a new species. Whether this form is really *A. vibrayeana* or not can only be determined by a comparison with French specimens.

It may be mentioned that d'Orbigny does not seem to have seen any specimens of the typical *A. affinis* from Blackdown, the form which he figures under that name (Pl. 167, figs. 4–6) being a Neocomian species, which he subsequently renamed *A. marullensis*, (*see* the Prodrome, Tom II. p. 67).

Natica Genti, *Sow.*

1816. Helix Gentii, *Sow.* Min. Con., p. 101, pl. 145.

1822. Ampullaria canaliculata, *Mant.* Geol. Sussex, p. 87, pl. 19, fig. 13.

1836. Natica canaliculata, *J. Sow.* Trans. Geol, Soc., Ser. 2, vol. iv. p. 336, pl. 11, fig. 12.

1842. Natica gaultina, *d'Orb.* Pal. Fr. Terr. Cret., t. 2, p. 156, pl. 173, figs. 3, 4.

1847. Natica Geinitzi, *d'Orb.* Prodrome 20th Etage, p. 150, No. 97.

Specimens from the micaceous sandstone or gaize of Devizes were named *Helix Gentii* by Sowerby in 1816, and we cannot see any specific differences between the Devizes form and those from the Gault which have been called *N. canaliculata* and *N. gaultina*.

Messrs. Pictet and Roux gave exactly the same synonomy in their "Moll. des Grès Verts," p. 184, but they were apparently uncertain about the identity of *Helix Gentii*, and they passed over Mantell's name of *canaliculata* without remark, retaining d'Orbigny's name *gaultina*.

D'Orbigny refers to *N. canaliculata*, Geinitz, non Mant., in his "Prodrome 20th Etage," p. 150, No. 97, and regarding it as different from Mantell's fossil, he proposes a new name, *N. Geinitzi* for the *N. canaliculata* of Geinitz. Messrs. Briart and Cornet, in their "Meule de Bracquegnies," p. 26, make the mistake of

thinking it was Sowerby's shell which d'Orbigny renamed, hence they describe it under the name of *N. Geinitzii*, but say nothing about *N. gaultina*.

Natica rotundata, *Sow.*

1823. Turbo rotundatus, *J. Sow.* Min. Con., pl. 433, fig. 2.
1835. Littorina rotundata, *J. Sow.* M. C. Index, vol. vi., p. 246.
1842. Littorina pungens, *Leym.* (non *Sow.*). Mem. Soc. Geol. de France, t. v. p. 31.
1842. Natica clementina, *d'Orb.* Terr. Cret. II. p. 154, pl. 172, fig. 4.
1849. Natica clementina, *Pict. et Rx.* Grès Verts, p. 179, pl. 17, fig. 1.
1849. Natica ervyna, *Pict. et Rx.* (non *d'Orb*) Grès. Verts. p. 180, pl. 17, fig. 2.
1850. Natica rotundata, *d'Orb.* Prodr. II., Et cenomanien, p. 150.
1250. Natica clementina, *d'Orb.* Prodr. II., Et albien, p. 129.
1865. Natica rotundata, Sow. In *Briart and Cornet,* p. 24, pl. II. fig. 19, 20.

The above synonomy was worked out by Prof. Renevier in 1856 and published in the "Bulletin de la Société vaudoise des Sciences Naturelles," vol. v., p. 54. He points out that Forbes (Quart. Journ. Geol. Soc., vol. i., p. 346) had united *Ampullaria lævigata,* Desh., with *Turbo rotundatus,* Sow., but that he himself, after an examination of the type specimens, was satisfied that they were distinct; the former occurring in the Aptien of France and in the Lower Greensand of England, while the type of *T. rotundatus* came from Blackdown. He also assured himself that the latter could not be distinguished from the *clementina* of d'Orbigny, but was the same species, Sowerby's name thus having the priority.

He also remarks that the *N. ervyna* of Pictet and Roux is not the species so named by d'Orbigny, but closely corresponds with specimens of the English *T. rotundata.*

He accepts the dictum of Forbes (*loc. cit.*) that *Littorina pungens,* Sow., is a distinct species.

As Prof. Renevier wrote after a careful examination of English and Continental types, we are disposed to accept his conclusions, which should banish the name *N. clementina* from modern lists.

Cardium gentianum, *Sow.*

1812. Cardita tuberculata, *Sow.*, Min. Con. vol. ii. p. 97, pl. 143.
1829. Cardium gentianum, *Sow.*, Min. Con. vol. vi. p. 242.
1843–47. ? Cardium Moutonianum, *d'Orb.*, Pal. Franc. vol. iii. p. 34, pl. 248.

This shell was originally described by Sowerby as a *Cardita,* the specimen being obtained "from the micaceous sand cut through in making the Devizes Canal" and lent to him by Mrs.

Gent. Later, however, he ascertained that it was a *Cardium* and renamed it *gentianum* (*see* Index to Sowerby, vol. vi. p. 242).

D'Orbigny appears to have been unaware of this correction and renaming, for he identifies his *Cardium moutonianum* with Sowerby's *Cardita tuberculata*, but says, "in placing it in the genus Cardium we cannot preserve his specific name because Linnæus described a *Cardium tuberculatum*." It may be a question, however, whether *moutonianum* is really identical with *gentianum*; only comparison of the types can decide this.

Cardium gentianum is only known from casts which have been squeezed by vertical pressure into the external mould of the shell after the solution of the latter. Its ornamentation is consequently not very clear, but it would seem that the rows of tubercles were largest on the posterior side of the shell and were much smaller and closer set on the anterior side.

C. proboscideum (Min. Con. Tab. 156, f. 1) is nearly allied, but differs in having strong spiniferous ribs all over the shell, two smaller ribs with frequent spines alternating with single strong ribs with larger spines. This species is at present only known from the Blackdown beds.

Lima parallela, *d'Orb. non Sow.*

1829. ? Plagiostoma elongata, *Sow.* Min. Con., Vol. vi., pl. 559, fig. 2. upper figure only.

1843-47. Lima parallela, *d'Orbigny.* Pal. Fr. Terr. Cret. p. 539, pl. 416, figs. 11–14.

Lima parallela, of many authors.

This *Lima*, which is the common form met with in the Gault, has for many years been known as "*Lima parallela*," in consequence of d'Orbigny having included Sowerby's two species, *Modiola parallela* (Min. Con., pl. 9), and *Plagiostoma elongata* in one species.

Sowerby's *Plagiostoma elongata* (*loc. cit.*) includes two specimens (now in the British Museum); the lower figure represents one from the Chalk, and does not concern us at present. The specimen indicated by the upper figure is from Folkestone, and is in a dark greenish grey sandy rock, with many chloritic grains, a matrix corresponding with the *A. mammillatus* beds at the base of the Gault. There are no other examples of this fossil, from the same horizon, in the British or Jermyn Street Museums. The specimen itself being only an internal cast, and consequently showing none of the external character, is very difficult to compare; but it agrees very well with external casts from other parts of the Gault, which are undoubtedly the same as d'Orbigny's *L. parallela*, and it is highly probable that it is the same species. One hesitates, however, to place the two forms together until additional evidence has been obtained from the *A. mammillatus* beds. And it seems better not to disturb the nomenclature, as Mr. Woods will, before long, have to study these forms for his Memoir in the Palæontographical Society's publications, but to let the name remain as *Lima parallela* d'Orb. non Sow.

The common Gault shells included in the latter name are found both at Folkestone, Black Ven, and other localities, and have been well described by d'Orbigny. These shells have angular ridges, less strongly developed anteriorly than posteriorly, and the entire surface ornamented with longitudinal lines crossed by lines of growth. Many specimens, although apparently quite perfect, do not show the longitudinal lines. Even the best preserved shells show no thread line at the bottom of the groove.

Sowerby's type of *Modiola parallela* (Min. Con. pl. 9) is in a coarse darkish sandstone, and, although little more than an internal cast, presents characters which on comparison with specimens from the Lower Greensand of Lympne and Sandgate, leave no doubt as to their being the same form: and as one or two of these have parts of the shell preserved, presenting characters distinct from the Gault species, known as *Lima parallela*, d'Orb. non Sow., it is necessary to keep them as distinct species, as was done by Sowerby. The Lower Greensand, *Lima* (*Modiola*) *parallela*, Sow., has angular ridges, which become almost obsolete on the anterior part of the shell, and, indeed, cannot be seen on some of the internal casts. Posteriorly, both at the summit of each ridge and at the bottom of each groove there is a well-marked thread-like line, but these threads are not seen at the anterior part of the shell.

It is highly probable that *Lima cottaldina* of d'Orbigny (Pal. Fr. Terr. Cret. p. 537, pl. 416, figs. 1–5, 1843–47) is the same as the *Modiola parallela* of Sowerby (1812).

There is a *Lima* of this same type in the British Museum from the Greensand of Blackdown, which has strongly angular ribs, and on the posterior part of the shell a distinct thread-line at the bottom of the groove, but anteriorly the thread is replaced by two or more fine lines; indeed, this shell seems to agree with what we now know of the characters of *Lima* (*Modiola*) *parallela*, Sow., and *Lima cottaldina*, d'Orb., from Lower Greensand horizons, and it will be extremely interesting if we find this species reappearing in the Upper Greensand.

LUCINA (ERIPHYLA) LENTICULARIS, *Goldf.*

1834–40. Lucina lenticularis, Goldf., Petref. Germ., p. 228, Tab. 146, f. 16.

1840–42. Lucina Reichii and L. circularis, Gein. Charact. der Schichten &c., II. p. 49, Taf. 16, f. 7, and III. p. 76, Taf. 20, f. 4.

1841. Lucina Reichii and L. lens, Rœmer, Norddeutsch. Kreid. p. 73, Taf. 9, fig. 14, 15.

1843. Lucina lenticularis, Geinitz, Verstein von Kiesl., p. 13, Taf. 2 figs. 4–6.

1846. Lucina lenticularis, Reuss, Böhm. Kreidef. II. p. 4, Taf. 33, figs. 20–23; Taf. 37, f. 17; Taf. 41, f. 10.

1871. Eriphyla lenticularis, Stolicska, Cret. Pelecypoda of South India, p. 181, pl. 6, figs. 7–13.

1872. Eriphyla lenticularis, Geinitz, Das Elbthalge. in Sachsen, II. p. 62, Taf. 17, f. 1, 2.; Taf. 18, fig. 1, 2.

The shell which we refer with some doubt to the above species is not uncommon in the zone of *Am. rostratus*, but has not

hitherto been identified. We are by no means sure that it is the *Lucina lenticularis* of Goldfuss, but a comparison of the best specimens with the excellent figures of Reuss and Geinitz has suggested the possibility of the identification. It is nearly orbicular, but compressed, shell thin and concentrically striated, umbones rather pointed and curved forward. In the softer sands specimens are sometimes distorted. The shell varies in size according to age and habitat from $\frac{5}{8}$ths of an inch to $1\frac{1}{4}$ inch across.

L. lenticularis differs from *Astarte striata*, Sow., which is probably also a *Lucina* or *Eriphyla*, in the much less convexity of its valves, a character which specimens from the hard grey sandstone of Potterne, near Devizes, show to be natural and not the result of compression.

When crushed it is not easy to distinguish the shells which we believe to have been *Lucina* from individuals of *Cytherea caperata*, Sow.

The shell figured by Pictet and Roux under the name of *Astarte dupiniana* may possibly be the same as our *Lucina*.

PECTEN ELONGATUS, *Lam.*

There are two forms of Pecten in the Upper Greensand which have been referred to this species, and about which there is much uncertainty; for, in the first place, we are doubtful whether they are distinct or are only varieties of one species, and, in the second, we are still more doubtful whether either of them can be identified as the *P. elongatus* of Lamarck.

The one form is in all probability that figured by Goldfuss in 1834 under the name of *P. cretosus*; but as that name had been applied previously by Defrance to another species, Rœmer in 1841 proposed the name of *crispus* for the shell described by Goldfuss.

The other form bears great resemblance to that figured by Sowerby in 1822 (Min. Conch., Pl. 370) under the name of *P. obliquus*, but as the type of this is not in the British Museum we have not been able to compare the actual shells.

Both these forms possess numerous ribs, which are mostly arranged in groups of three—one large median rib with two smaller laterals, but sometimes there is only one lateral. All the ribs are ornamented with close-set scale-like imbrications. The two forms differ chiefly in the number of the ribs, in their regularity, and in the prominence of the scales.

Geinitz (Elbthalg, in Sachsen I. Taf. 44, f. 2–4) figures under the name of *P. elongatus* what seems to be an extreme form of this species or group, with very numerous ribs; but we cannot accept his synonymy, and he does not discuss the name.

We may add that the *P. elongatus* of d'Orbigny is unlike either of our shells, and was by himself admitted to be distinct from the *P. crispus* of Goldfuss (*see* Prodrome II., p. 169).

It may possibly be found desirable to adopt the name of *P. crispus* for one or both of the shells we have in view, but for the present that of *P, elongatus,* which has been so long in use, is allowed to stand.

PECTEN HISPIDUS, *Goldf.*

1834. Pecten hispidus, *Goldfuss.* Pet. Germ. II. p. 59, Taf. 94, f. 4.
1850. Pecten hispidus, *d'Orbigny.* Prodr. II. p. 169.
1872. Pecten hispidus, *Geinitz.* Elbthalg. in Sachsen, p. 197, pl. 44, f. 9, 10.

We believe that Prof. Barrois was the first to identify this *Pecten* both in France and in England. He records it from his zones of *Am. rostratus* and *Pecten asper* (Gaize and Sables de la Hardoye) in the Ardennes,[1] and in England from the equivalent of the Gaize at Lulworth and in the Isle of Wight.[2]

This species is from 1½ to 2 inches in length, ornamented with numerous narrow ribs, which bear at intervals sharp triangular pointed scales or spines. Goldfuss describes the interspaces as flat and smooth (*planis levibus*), but his enlarged figure shows a faint oblique striation near the sides of the shell. This is also perceptible in some English specimens.

Geinitz gives fairly good figures of this species, some of them showing the sharp, erect, short spines very clearly; though his enlarged view, being drawn as seen from above, does not show them well; but he says the ribs bear erect scales placed at moderate distances apart.

This is the shell described by one of us in 1886 under the name of *Pecten sp.*,[3] and we can now state that Mr. W. Hill obtained an example of it from the Cenomanian of Lizores (Orne, France).

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[1] Terrain Crétacé des Ardennes, pp. 303 and 324 (1878).
[2] Recherches sur le Terr. Crét. de l'Angleterre, pp. 91 and 106 (1876).
[3] Quart. Journ. Geol. Soc., vol. lii. p. 152.

APPENDIX.

B.—GENERAL LIST OF FOSSILS FROM THE SELBORNIAN OR GAULT AND UPPER GREENSAND OF ENGLAND.

The following catalogue has been compiled from many sources. In the first place it includes all the local lists which have been given in the text of this volume, and all the species which have been specially collected by Mr. J. Rhodes and by myself, and determined by Messrs George Sharman and E. T. Newton during the progress of the work on which this memoir is based.

For the fossils of the Gault of Folkestone (other than Entomostraca and Foraminifera) our authority is Mr. F. G. Hilton Price, whose lists were published in the Quarterly Journal of the Geological Society (vol. xxx., p. 342), and in his subsequent little treatise on the Gault (1879). The Foraminifera of the Gault have been the subject of a series of papers by Mr. F. Chapman in the Journal of the Royal Microscopical Society (from 1892 to 1898), with a classified list in the concluding paper of the series. A list of the Entomostraca was given by Messrs. Chapman and Sherborn in the Geological Magazine (Dec. 3, vol. x., p. 345).

Lists of the fossils of the Red Chalk have been given by Messrs. H. G. Seeley, T. Wiltshire, W. Whitaker, W. Hill and others, and its Foraminifera have been recorded by Messrs. Burrows, Sherborn and Bailey. These lists, so far as they related to Hunstanton, were combined and added to by myself in a memoir on the Borders of the Wash (Mem. Geol. Survey, 1899). For the present memoir all the lists have been consulted again.

The entries of Blackdown and Haldon fossils are chiefly from the revised list given by the late Rev. W. Downes, in Quart. Journ. Geol. Soc., vol. xxxviii., p. 75, supplemented by the lists from Sidmouth and Haldon given in chapter xiv.

The nomenclature of the Polyzoa stands in much need of revision, but this has been undertaken by Dr. J. W. Gregory, and we could do no more than quote the lists which have been published by the late Mr. G. R. Vine.

The list of Corals is based on the lists given by Duncan in his Supplements to the Pal. Soc. Monograph on the Fossil Corals, but we have accepted the important corrections and additions made by Mr. R. F. Tomes in the Geological Magazine (1885 & 1899).

The list of Sponges is taken from that given by Dr. G. J. Hinde in his Illustrated Catalogue of the Cretaceous Sponges in the British Museum.

An endeavour has been made to indicate the localities or districts in which each species has been found, so far as they are known to

us, letters being used as abbreviations of the names of places and counties; these are as follows:—

Be.	Bedfordshire.	Hl.	Haldon.	Nor.	Norfolk.
Bk.	Berkshire.	Hun.	Hunstanton.	Pun.	Punfield.
Bu.	Bucks.	IW.	Isle of Wight.	R.	Ringmer.
Bl.	Blackdown.	LR.	Lyme Regis.	S.D.	South Dorset.
BV.	Black Ven, Dorset.	Li.	Lincolnshire.	Su.	Surrey.
De.	Devizes.	Lul.	Lulworth.	Sid.	Sidmouth.
Dev.	Coast of Devon.	K.	Kent.	Sp.	Speeton.
Dor.	Dorset.	MB.	Maiden Bradley in Wilts.	W.	Wilts.
E.	Eastbourne.	Mel.	Melbury, near Shaftesbury.	WD	West Dorset.
F.	Folkestone.	N.D.	North Dorset.	War.	Warminster.
Go.	Golden Cap.			Yo.	Yorkshire Wolds.
Ha.	Hants.				

N.B.—The column headed "Cambridge Greensand" includes the derived fossils only.

SPECIES	Found also in Lower Cretaceous.	Lower Gault. Mammillatus Zone.	Lower Gault. Lower Gault Clays.	Zone of Amm. rostratus. Upper Gault.	Zone of Amm. rostratus. Malmstone and Sands.	Zone of Amm. rostratus. Blackdown and Haldon.	Cambridge Greensand.	Red Chalk.	Zone of Pecten asper. Lower Beds.	Zone of Pecten asper. Chert Beds.	Zone of Pecten asper. Highest Beds.	Range into Chalk.	Gault.	Upper Greensand.	LOCALITIES AND REMARKS.
	*	1	2	3	4	5	6	7	8	9	10	†	g	s	
AVES.															
Enaliornis Barretti, *Seeley*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
„ Sedgwicki, *Seeley*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
REPTILIA.															
Ornithosauria.															
Ornithocheirus compressirostris, *Owen.*	–	–	–	3	–	–	–	–	–	–	–	†	–	–	(= Pterodactylus), 3 Folkestone.
„ Cuvieri, *Bowerb.*	–	–	–	–	–	–	6	–	–	–	–	†	–	–	—
„ Daviesi, *Owen*	–	–	–	–	–	–	6	–	–	–	–	–	g	–	(= ? O. denticulatus, Seeley. Ornith. Pl. xii. f. 8.
„ machærorhynchus, *Seeley.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	Ornithosauria Pl. xii. f. 1.
„ Sedgwicki, *Owen*	–	–	2	–	–	–	6	–	–	–	–	–	–	–	(=Coloborhynchus, Owen.)
„ simus, *Owen*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	(*Criorhynchus*, Owen.)
„ *Woodwardi, Ow.* (*see* O. simus).															— –
„ (other species)	–	–	–	–	–	–	6	–	–	–	–	–	–	–	Species named by Prof. Seeley, but not described.
Ornithostoma sp.	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
Dinosauria.															
Eucercosaurus tanyspondylus, *Seeley.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
Patricosaurus merocratus, *Seeley*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
Syngonosaurus macrocercus, *Seeley.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
Titanosaurus sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	s	Isle of W.

SPECIES.		Lower Gault.		Zone of Amm. rostratus.					Zone of Pecten asper.						LOCALITIES AND REMARKS.
	* Found also in Lower Cretaceous.	1 Mammillatus Zone.	2 Lower Gault Clays.	3 Upper Gault.	4 Malmstone and Sands.	5 Blackdown and Haldon.	6 Cambridge Greensand.	7 Red Chalk.	8 Lower Beds.	9 Chert Beds.	10 Highest Beds.	† Range into Chalk.	g Gault.	s Upper Greensand.	
REPTILIA—cont.															
Ichthyopterygia.															
Cetarthrosaurus Walkeri, *Seeley*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
Ichthyosaurus campylodon, *Carter.*	–	1	2	3	–	–	6	7	–	9	–	†	–	–	1 F. 2, 3 many places. 7 H.
Ophthalmosaurus cantabrigiensis, *Lyddeker.*		–	–	–	–	–	6	–	–	–	–	–	–	–	—
Crocodilia.															
Crocodilus ? cantabrigiensis, *Seeley.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
„ ? icenicus, *Seeley* -	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
Sauropterygia.															
Cimoliosaurus Bernardi, *Owen* -	*	–	–	–	–	–	6	–	–	–	–	†	–	–	—
„ constrictus, *Owen*	–	–	2	–	–	–	6	–	–	–	–	†	–	–	(= Mauisaurus Gardneri, Seeley.)
„ cantabrigiensis, *Lyd.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
„ latispinus, *Owen*	–	–	–	–	–	–	6	7	–	–	–	–	–	–	7 H.
„ planus, *Owen* -	–	–	–	–	–	–	6	–	–	–	–	†	–	–	—
„ (other species) -	–	–	–	–	–	–	6	–	–	–	–	–	–	–	Named by Prof. Seeley but not yet described.
Plesiosaurus (*see* Cimoliosaurus).															
Polyptychodon interruptus, *Owen.*	–	–	2	3	–	–	6	–	–	9	–	†	–	–	—
Chelonia.															
Chelone Benstedi, *Owen* -	–	–	–	–	–	–	–	–	–	–	–	–	g	–	g. Folkestone.
„ Jessoni, *Lyd.*	–	–	–	–	–	–	6	–	–	–	–	–	g	–	g. Folkestone.
Hylæochelys lata, *Owen* - -	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 I. of Wight.
Rhinochelys cantabrigiensis, *Lyd.*	–	–	–	–	–	–	–	6	–	–	–	–	–	–	—
„ brachyrhina, *Lyd.*	–	–	–	–	–	–	–	6	–	–	–	–	–	–	—
„ elegans, *Lyd.* -	–	–	–	–	–	–	–	6	–	–	–	–	g	–	g. Folkestone.
„ Jessoni, *Lyd.* -	–	–	–	–	–	–	–	6	–	–	–	–	–	–	—
„ macrorhina, *Lyd.*	–	–	–	–	–	–	–	6	–	–	–	–	–	–	—
„ pulchriceps, *Owen.*	–	–	–	–	–	–	–	6	–	–	–	–	–	–	—
„ sp. - -	–	–	–	–	–	–	–	6	–	–	–	–	–	–	—
Protostega anglica, *Lyd.* - -	–	–	–	–	–	–	–	6	–	–	–	–	–	–	—
Trachydermochelys phlyctænus, *Seeley.*	–	–	–	–	–	–	–	6	–	–	–	–	–	–	—

SPECIES.	Found also in Lower Cretaceous. *	Lower Gault. Mammillatus Zone. 1	Lower Gault. Lower Gault Clays. 2	Zone of Amm. rostratus. Upper Gault. 3	Zone of Amm. rostratus. Malmstone and Sands. 4	Zone of Amm. rostratus. Blackdown and Haldon. 5	Cambridge Greensand. 6	Red Chalk. 7	Zone of Pecten Asper. Lower Beds. 8	Zone of Pecten Asper. Chert Beds. 9	Zone of Pecten Asper. Highest Beds. 10	Range into Chalk. †	Gault. g	Upper Greensand. s	LOCALITIES AND REMARKS.
PISCES.															
Elasmobranchii.															
Acrodus levis, *A. S. W.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
Cestracion canaliculatus, *Eg.*	–	–	–	3	–	–	6	7	–	–	–	†	g	–	3 F. 7 H.
Corax falcatus, *Ag.*	–	–	–	–	–	–	–	–	–	9	–	†	–	–	(= C. heterodon, *Reuss.*)
„ pristodontus, *Ag.*	–	–	–	3	–	–	–	–	–	–	–	†	–	–	E.
Lamna appendiculata, *Ag.*	–	1	2	3	4	–	6	7	8	9	10	†	–	–	Common at most places.
„ *acuminata* (=Oxyrhina Mantelli).															
„ macrorhiza, *Cope*	–	–	2	3	–	–	6	–	–	–	10	†	g	–	Recorded as L. gracilis, Ag. 2 Nor, 3 F. 10 War.
Notidanus lanceolatus, *A. S. W.*	–	–	–	–	–	–	–	–	–	–	–	–	g	–	—
„ microdon, *Reuss*	–	–	–	–	–	–	–	7	–	–	–	†	–	–	7 H. (?).
Oxyrhina angustidens, *Reuss.*	–	–	–	–	–	–	–	–	–	9	–	†	–	–	—
„ Mantelli, *Ag.*	–	–	–	–	–	–	6	–	–	–	–	†	–	–	(=Lamna acuminata.)
„ macrorhiza, *Pict. & Camp.*	–	–	–	–	–	–	6	–	–	–	–	–	g	–	—
Ptychodus decurrens, *Ag.*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 N.D.
„ mammillaris ? *Ag.*	–	–	–	–	–	–	–	–	–	9	–	†	–	–	—
„ sp.	–	–	–	3	–	–	6	–	–	–	–	–	–	–	—
Scapanorhynchus gigas, *A. S. W.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
„ raphiodon, *Ag.*	–	–	–	–	–	–	6	–	–	–	–	†	–	–	3 F. E.
„ subulatus, *Ag.*	–	–	–	3	–	–	6	–	–	9	–	†	g	–	—
Sphenonchus sp. (= Hybodus)	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
Synechodus dubrisiensis, *Mackie*	–	–	–	–	–	–	–	–	–	–	–	†	g	–	(= Hybodus.)
„ recurvus, *Trautsch.*	–	–	–	–	–	–	–	–	–	–	–	–	g	–	—
„ sp.	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 Dor.
Chimæroidei.															
Edaphodon crassus, *Newton*	–	–	–	–	–	–	6	–	–	9	–	†	–	–	
„ laminosus, *Newton*	–	–	–	3	–	–	6	–	–	–	–	–	g	–	3 F.
„ Mantelli, *Buckl.*	–	–	–	–	–	–	6	–	–	–	–	†	–	–	—
„ Reedi, *Newton*	–	–	–	–	–	–	6	–	–	–	–	†	–	–	—
„ Sedgwicki, *Ag.*	–	–	–	3	–	–	6	7	–	–	–	†	–	–	3 F. 7 H.
„ sp.	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
Ischyodus incisus, *Newton*	–	–	–	–	–	–	–	–	–	–	–	†	g	–	—
„ latus, *Newton*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
„ planus, *Newton*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
„ Thurmanni, *P & C.*	–	–	–	–	–	–	6	–	–	–	–	†	–	–	—
Teleostomi (Ganoids).															
Anomœodus angustus, *Ag.*	–	–	–	–	–	–	6	–	–	9	–	–	g	–	=(Cælodus cretaceus.)
„ superbus, *A. S. W.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
Athrodon Jessoni, *A. S. W.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
„ crassus, *A. S. W.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
„ sp.	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 Nor.
„ sp.	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
Belonostomus sp.	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—

SPECIES.	* Found also in Lower Cretaceous.	Lower Gault. Mammillatus Zone. 1	Lower Gault. Lower Gault Clays. 2	Zone of Amm. rostratus. Upper Gault. 3	Zone of Amm. rostratus. Malmstone and Sands. 4	Zone of Amm. rostratus. Blackdown and Haldon. 5	Cambridge Greensand. 6	Red Chalk. 7	Zone of Pecten Asper. Lower Beds. 8	Zone of Pecten Asper. Chert Beds. 9	Zone of Pecten Asper. Highest Beds. 10	† Range into Chalk.	g Gault.	Upper Greensand.	LOCALITIES AND REMARKS.
PISCES—cont.															
***Teleostomi* (*Ganoids*)—cont.**															
Cœlodus ellipticus, *Ag.*	–	–	–	–	–	–	–	–	–	–	–	–	g	–	—
„ inæquidens, *A. S. W.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
„ parallelus ? *Ag.*	–	–	–	–	–	–	6	–	–	–	–	†	–	–	—
„ sp.	–	–	–	3	–	–	6	–	–	–	–	–	–	–	—
Gyrodus	–	–	–	–	4	–	–	–	–	–	–	–	–	–	—
Lepidotus	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
Pisodus ?	–	–	2	–	–	–	6	–	–	–	–	–	–	–	—
(Teleosteans.)															
Beryx, sp.	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 Nor.
Cimolichthys ? striatus, *Ag.*	–	–	2	–	–	–	6	–	–	–	–	†	–	–	2 Nor.
Enchodus lewesiensis, *Mant.*	–	–	–	–	–	–	6	–	–	9	–	†	g	–	—
„ sp.	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
Ichthyodectes minor, *Eg.*	–	–	–	–	–	–	6	–	–	–	–	†	–	–	(= Hypsodon.)
Plethodus expansus, *Dixon*	–	–	–	–	–	–	6	–	–	–	–	†	–	–	—
Pachyrhizodus glyphodus, *Blake*	–	–	–	3	–	–	6	–	–	–	–	–	g	–	—
Portheus gaultinus, *Newton*	–	–	–	–	–	–	6	–	–	–	–	†	g	–	(=Xiphactinus, *Leidy*.
Protosphyræna ferox, *Leidy*	–	–	–	–	4	–	6	–	–	9	–	†	–	–	4 De., Ha.
„ sp.	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
Thrissopater salmoneus, *Günther*	–	1	–	–	–	–	–	–	–	–	–	–	–	–	—
CEPHALOPODA.															
Ammonoidea.															
Ammonites—															
[Acanthoceras] brottianus *d'Orb*, var. sexangulatus, *Seeley*.	–	–	–	–	–	–	6	–	–	–	–	–	–	–	(*See* p. 442).
„ *gardonicus* (*see* rhamnonotus).															
„ itierianus, *d'Orb.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F. (Bed VIII.).
„ mammillatus, *Schloth.*	–	1	–	–	–	–	–	–	–	–	–	–	–	–	1 F. Ha. Sur. Dor.
„ Mantelli, *Sow.*	–	–	–	–	4	–	–	–	–	–	10	†	–	–	4 Ha. 10 War. Dor.
„ navicularis, *Mant.*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 War. Dor.
„ rhamnonotus, *Seeley.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	(=gardonicus, Hebert)
„ *sexangulatus, Seeley* (*see* brottianus).															
[Desmoceras] Beudanti, *Brong.*	–	1	2	3	–	–	–	7	–	–	–	–	–	–	(See p. 442), 1 F. Su. Nor. Common in 2. 3 F.
„ latidorsatus, *Mich.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	Rare.
„ *lævigatus, Sow.* (*see* Beudanti)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	

SPECIES.	Found also in Lower Cretaceous.	Lower Gault. Mammillatus Zone.	Lower Gault. Lower Gault Clays.	Zone of Am. rostratus. Upper Gault.	Zone of Am. rostratus. Malmstone and Sands.	Zone of Am. rostratus. Blackdown and Haldon.	Cambridge Greensand.	Red Chalk.	Zone of Pecten asper. Lower Beds.	Zone of Pecten asper. Chert Beds.	Zone of Pecten asper. Highest Beds.	Range into Chalk.	Gault.	Upper Greensand.	LOCALITIES AND REMARKS.
	*	1	2	3	4	5	6	7	8	9	10	†	g	s	
CEPHALOPODA—Cont.															
Ammonoidea—Cont.															
Ammonites—*Cont.*—															
[Desmoceras] *mayorianus, d'Orb.* (*see* planulatus).															
„ planulatus, *Sow.*	–	–	–	3	4	–	6	7	–	–	–	†	–	–	(=Mayorianus,d'Orb.) 3 F. 4De.Bu. 7 Hun.
„ sphærotus, *Seeley*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ versicostatus, *Mich.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F. (Bed VII.).
[Hoplites] auritus, *Sow.* - -	–	–	2	3	4	–	6	7	–	–	–	–	–	–	Common in 2, 3, 4, 6. 7 Hun. Yo.
„ „ var. catillus, *Sow.* -	–	–	–	–	4	–	–	–	–	–	–	–	–	–	(*See* p.). 4 De. Ha. Bu. I.W.
„ benettianus, *Sow.* -	–	1	2	–	–	–	–	–	–	–	–	–	–	–	(= Deluci, Brong.) 1 W. N. Dor. 2 passim.
„ *catillus* (*see* auritus).															
„ cœlonotus, *Seeley.*	–	–	2	3	–	–	6	–	–	–	–	–	–	–	(= valbonensis, Hebert). 2 F. 3 F. E.
„ *cratus, Seeley* = var. of raulinianus.	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
„ *Deluci, Brong.*, *see* benettianus.															
„ denarius, *Sow.* -	–	–	2	3	4	–	–	–	–	–	–	–	–	–	2 common. 3 F. E. 4, De. I.W.
„ Deshayesi ? *Leym.*-	–	–	2	–	4	–	–	7	–	–	–	–	–	–	2 F.Wilts. 4 De. 7 Yo.
„ falcatus, *Mant.* -	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 War. M.B. Dorset.
„ fissicostatus, *d'Orb.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F. (rare.)
„ Guersanti, *d'Orb.* -	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ glossonotus, *Seeley*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	(Very rare.)
„ interruptus, *Brong.*	–	1	2	–	?	–	–	7	–	–	–	–	–	–	Common in 1 and 2. 4 De. ? 7 Hun. Li.
„ lautus, *Sow.* -	–	–	2	3	–	–	–	7	–	–	–	–	–	–	Common in 2. 3 E. Nor. 7 Hun.
„ ochetonotus, *Seeley.*	–	–	2	3	–	–	–	7	–	–	–	–	–	–	2 Bu. 3 Kent. 7 Hun.
„ raulinianus, *d'Orb.*	–	–	2	3	4	–	6	–	–	–	10	–	–	–	Common in 2, 3, and 6, 4 I.W. Lul. 10 Dor. (? derived.)
„ renauxianus, *Sharpe*, non *d'Orb.*	–	–	–	3	4	–	6	–	–	–	10	†	–	–	4 Ha. I.W. De. 10 Dor.
„ Salteri, *Sharpe* -	–	–	–	–	–	–	6	–	–	–	10	†	–	–	10 N. Dor.
„ selliguinus, *Brong.*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	(? = lævigatus).
„ splendens, *Sow.* -	–	–	2	3	4	–	6	7	–	–	10	–	–	–	Common in 2. 3 F. 4 De. Lul. 7 Hun. 10 Dor.
„ Studeri, *P. and C.*-	–	–	–	3	–	–	6	–	–	–	10	–	–	–	3 F. 10 Dor (derived).
„ tetragonus, *Seeley* -	–	–	–	–	–	–	6	–	–	–	–	–	–	–	(? a var. of auritus).
„ tuberculatus, *Sow.*-	–	–	2	3	–	–	–	7	–	–	–	–	–	–	Common in 2. 3 F. E. 7 Hun.
„ *valbonensis, Heb.* (*see* cœlonotus).															
„ vraconensis, *P. and C.*	–	–	–	–	–	–	6	–	–	–	10	–	–	–	10 N. Dor. (derived).
„ Woodwardi, *Seeley*	–	–	–	–	–	–	6	–	–	–	–		g	–	
[Lytoceras] timotheanus, *Pictet*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
[Placenticeras] *complanatus, Sow.* (*see* largilliertianus).															
„ largilliertianus, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 War.
[Phylloceras] vellidæ, *Mich.* -	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F. (Bed VIII.).

SPECIES.	Found also in Lower Cretaceous.	Lower Gault. Mammillatus Zone.	Lower Gault. Lower Gault Clays	Zone of Am. rostratus. Upper Gault.	Zone of Am. rostratus. Malmstone and Sands.	Zone of Am. rostratus. Blackdown and Haldon.	Cambridge Greensand.	Red Chalk.	Zone of Pecten asper. Lower Beds.	Zone of Pecten asper. Chert Beds.	Zone of Pecten asper. Highest Beds.	Range into Chalk.	Gault.	Upper Greensand.	LOCALITIES AND REMARKS.
	*	1	2	3	4	5	6	7	8	9	10	†	g	a	
CEPHALOPODA—Cont.															
Ammonoidea—Cont.															
Ammonites—*Cont.*— [Schlœnbachia] bouchardianus, *d'Orb.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 I.W. 3 F.
„ bronguiartianus, *Pictet.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F. (Bed VIII.).
„ candolleanus, *Pictet.*	–	–	–	3	–	–	6	–	–	–	–	–	–	–	(=? var. of rostratus)
„ cornutus, *Pictet.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ Coupei, *Brong.*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 Dor. War.
„ cristatus, *Deluc.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 Bu. Bd. 3 Kent.
„ Delaruei, *d'Orb*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F. (rare).
„ Goodhalli, *Sow.*	–	–	–	3	4	5	–	–	–	–	–	–	–	–	3 F. 4 De. Lul. 5 Bl.
„ hugardianus, *d'Orb.*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 De.
„ *inflatus*, *Sow.* (*see* rostratus).															
„ roissyanus, *d'Orb.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ rostratus, *Sow.*	–	–	2	3	4	5	6	7	8	–	10	–	–	–	(=inflatus, Sow.) 2 Bu. Bd. Common in 3 to 6. 7 Hun. Yo. 8 Wilts, Dor. 10 N. Dor.(derived).
„ variana, *Sow.*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 Dor. War.
„ varicosus, *Sow.*	–	–	2	3	4	5	6	–	–	–	–	–	–	–	2 Bd. Bu. Common in 3 and 4.
„ sp. - -	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Hal.
Ancyloceras spinigerum, *Sow.* -	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ tuberculatum, *Sow.*	–	–	–	3	4	–	6	–	–	–	–	–	–	–	3 K. E. 4 De.
Anisoceras alternatum, *Mant.* -	–	–	–	–	4	–	–	–	–	–	–	†	–	–	(=Hamites). 4 De. Lul.
„ armatum, *Sow.* -	–	–	–	3	4	–	6	–	–	–	10	†	–	–	Common in 3, 4, 6. 10 N. Dor.
„ saussureanum, *P. and C.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
Baculites baculoides, *Mant.* -	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 N. Dor.
„ Gaudini, *P. and C.* -	–	–	2	–	–	–	6	–	–	–	–	–	–	–	2 F.
Crioceras astierianum, *d'Orb.* -	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ occultum, *Seeley-* -	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
Hamites attenuatus, *Sow.* -	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. R. 3 F. K. E.
„ compressus, *Sow.* -	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 K. R.
„ desorianus, *Pictet* -	–	–	–	3	4	–	–	–	–	–	4	–	–	–	3 Bu. 4 De.
„ elegans, *Park.* - -	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
„ intermedius, *Sow.* -	–	–	2	3	–	–	–	6	–	–	–	–	–	–	2 (common). 3 K. Bu.
„ maximus, *Sow.* -	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 R. F. 3 E. F.
„ Sablieri, *d'Orb.* - -	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ tenuis, *Sow.* - -	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 R.
„ virgulatus, *d'Orb.* -	–	–	2	–	4	–	6	–	–	–	–	–	–	–	2 F. 4 Lul.
Helicoceras gracile, *d'Orb.* -	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ robertianum, *d'Orb.*	–	–	–	3	–	–	6	–	–	–	–	–	–	–	3 F.
„ rotundum, *Sow.* -	–	–	2	–	4	–	–	–	–	–	–	–	–	–	2 F. R. 4 De.
Ptychoceras adpressus, *d'Orb* -	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
Scaphites hugardianus, *d'Orb.* -	–	–	–	3	–	–	6	–	–	–	–	–	–	–	3 F.
„ Meriani, *P. & C.* -	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
„ æqualis, *Sow.* - -	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 Dorset (rare).

SPECIES.	Found also in Lower Cretaceous.	Lower Gault. Mammillatus Zone.	Lower Gault. Lower Gault Clays.	Zone of Am. rostratus. Upper Gault.	Zone of Am. rostratus. Malmstone and Sands.	Zone of Am. rostratus. Blackdown and Haldon.	Cambridge Greensand.	Red Chalk.	Zone of Pecten asper. Lower Beds.	Zone of Pecten asper. Chert Beds.	Zone of Pecten asper. Highest Beds.	Range into Chalk.	Gault.	Upper Greensand.	LOCALITIES AND REMARKS.
	*	1	2	3	4	5	6	7	8	9	10	†	g	s	
CEPHALOPODA—Cont.															
Ammonoidea—Cont.															
Toxoceras sp.	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 ? De.
Turrilites archiacianus, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	–	–	g	–	Gault of Folkestone.
„ astierianus, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	–	–	g	–	Gault of Folkestone.
„ Bechei, *Sharpe*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 Mel.
„ Bergeri, *Brong.*	–	–	–	3	–	–	6	–	–	–	10	†	–	–	3 F. 10 N. Dor.
„ catenatus, *d'Orb.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ costatus ? *Sow.*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 N. Dor. (doubtful).
„ elegans, *d'Orb.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ hugardianus, *d'Orb.*	–	–	2	–	–	–	6	–	–	–	–	–	–	–	2 F.
„ nobilis, *Jukes Br.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
„ puzosianus, *d'Orb.*	–	–	–	–	–	–	6	–	–	–	10	–	–	–	10 N. Dor. (? derived).
„ senequierianus, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	–	–	g	–	Gault of Folkestone.
„ tuberculatus, *Sow.*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 N. Dor.
„ Wiesti, *Sharpe*	–	–	–	–	–	–	6	–	–	–	–	†	–	–	
„ sp.	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
Belemnoidea.															
Belemnites minimus, *Lister*	–	–	2	3	4	–	6	7	–	–	–	–	–	–	(includes attenuatus and ultimus).
„ sp.	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 De. Lul. IW. 8 Mel. 10 War.
Nautiloidea.															
Nautilus albensis, *d'Orb.*	–	–	–	3	–	–	6	7	–	–	–	–	–	–	3 F. 7 Hun.
„ arcuatus, *Desh.*	–	–	–	–	–	–	6	–	–	–	–	–	g	–	g Folkestone.
„ atlas ? *Whiteaves*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 M.B.
„ bouchardianus, *d'Orb.*	–	–	2	–	–	–	6	7	–	–	–	–	–	–	2 F. E. BV. 7 Hun.
„ cantabrigiensis, *Foord*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
„ clementinus, *d'Orb.*	–	–	2	3	4	–	6	–	–	–	–	–	–	–	Common in 2. 3 Bu. 4 De.
„ deslongchampsianus, *d'Orb.*	–	–	–	–	–	–	–	–	–	9	10	†	–	s	10 War. M.B. s in IW.
„ elegans, *Sow.*	–	–	–	–	4	–	–	7	–	–	–	†	–	s	4 De. Hs. IW. 7 Yo. 9 IW.
„ expansus, *Sow.*	–	–	–	–	–	–	–	–	–	–	–	–	–	s	s. in IW.
„ Fittoni, *Sow.*	–	–	–	–	4	–	–	–	–	–	–	†	–	s	4 De. (doubtful). s in IW.
„ fleuriausianus, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	–	–	–	s	s De.
„ hunstantonensis, *Foord*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ laevigatus, *Sow.*	–	–	–	–	4	–	–	–	–	–	10	†	–	–	4 De. 8 Mel. 10 War. M.B.
„ largilliertianus, *d'Orb.*	–	–	–	–	–	–	6	–	–	–	10	–	–	–	10 War.
„ semiundatus, *Foord*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 De. Swanage.
„ undulatus, *Sow.*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 De. IW.
„ ventroplicatus *Foord*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 De.
Rhynchoteuthis 5-carinatus, *P. & C.*	–	–	–	–	–	–	–	–	–	–	–	–	g	–	Gault of Folkestone.
GASTEROPODA.															
Acmaea tenuicosta, *Sow.*	–	–	2	3	4	–	6	–	–	–	10	–	–	–	2 and 3 F. 4 De. 10 W.D.
„ tenuistriata, *Seeley.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	(? var. of tenuicosta).
„ sp.	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 N.D.

SPECIES.	Found also in Lower Cretaceous.	Lower Gault.		Zone of Am. rostratus.			Cambridge Greensand.	Red Chalk.	Zone of Pecten asper.			Range into Chalk.	Gault.	Upper Greensand.	LOCALITIES AND REMARKS.
		Mammillatus Zone.	Lower Gault clays.	Upper Gault.	Malmstone and Sands.	Blackdown and Haldron.			Lower Beds.	Chert Beds.	Highest Beds.				
	*	1	2	3	4	5	6	7	8	9	10	†	g	s	
GASTEROPODA—cont.															
Actæon affinis, *Sow.*	x ?	–	2	–	4	5	–	–	–	–	–	–	–	s	2 F. W.BV. 4 De. 5 Bl. Hl. Sid. s IW.
„ „ var. lacryma, *d'Orb.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	(=Ringinella lacryma d'Orb.) 5 Bl.
„ pyrostoma, *Seeley*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
„ cf. vibrayeana, *d'Orb.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
Actæonina formosa, *Sow.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 ND.
Aporrhais calcarata, *Sow.*	–	–	2	–	4	5	–	–	–	–	–	–	–	–	2 F. 4 De. 5 Bl. Sid.
„ carinata, *Mant.*	–	–	2	3	–	–	6	–	–	–	–	–	–	–	2 F.R. IW. ND. WD. 3 F. 3 F.E.
„ carinella, *d'Orb.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ cingulata, *P. & R.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 & 3 F.
„ doratochila, *Gard.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ elongata, *Sow.*	–	–	2	–	–	–	6	–	–	–	–	–	–	–	2 F.
„ globulata, *Seeley*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	(=probably var. of Ap. retusa.)
„ Griffithsi, *Gard.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ histochila, *Gard.*	–	–	2	–	4	–	6	–	–	–	–	–	–	–	2 F. 4 D. 5 Bl. (Tessarolax).
„ macrostoma, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	(Pterocerella.)
„ marginata, *Sow.*	–	–	2	3	–	–	6	7	–	–	–	–	–	–	(=A orbignyana, Pict.) 2 F.W.BV. 3 F. 7 N.
„ maxima, *Price*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ neglecta, *Gard.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
„ *orbignyana* (*see* marginata).															
„ oligochila, *Gard.*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	4 Lul.
„ Parkinsoni, *Mant.*	–	–	2	–	4	5	6	–	–	–	–	–	–	–	2 F. 4 Lul. IW. 5 Bl.
„ Cunningtoni, *Gard.*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 De.
„ retusa, *Sow.*	–	–	2	3	4	5	6	–	–	–	–	–	–	–	2 F.BV. 3 F. 4 De. 5 Bl. Sid. (Tessarolax)
„ toxochila, *Gard.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ tricostata, *d'Orb.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
Avellana cassis, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	(Cinulia.) 10 M.B. S. Dor.
„ dupiniana, *d'Orb.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ incrassata, *Sow.*	–	–	–	–	4	5	6	–	8	–	10	–	–	–	4 IW. 5 Bl. Hl. 8 Mel. 10 Dor. (darived).
„ inflata, *d'Orb.*	–	–	2	3	–	–	6	–	–	–	–	–	–	–	2 & 3 F. 2 W. Dor.
„ pulchella, *Price*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
Bellerophina minuta, *Sow.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
Brachystoma angularis, *Seeley*	–	–	2	–	–	–	6	–	–	–	–	–	–	–	2 F.
Buccinum gaultinum, *d'Orb.*	–	–	2	3	–	–	6	–	–	–	–	–	–	–	2 & 3 F.
Cadulus gaultinus, *Gard.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 & 3 F.
Cassidaria sp.	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
Calyptræa Cooksoniæ, *Seeley*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	(=C. Sanctæ-crucis, P. & C.)
„ concentrica, *Gard.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
Cinulia (*see* Avellana).															
Cerithium Chavannesi, *P. & C.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ ervynum, *d'Orb.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ gracile, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	(Littorina) 5 Bl.
„ mosense ? *Buv.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
„ ornatissimum, *d'Orb.*	–	–	–	3	–	–	–	7	–	–	–	†	–	–	3 Ely. 7 N.
„ Phillipsi, *Leym.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ subspinosum, *Desh.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 & 3 F.
„ tectum, *d'Orb.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 & 3 F.
„ trimonile, *Mich.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 & 3 F.
„ sp.	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ sp.	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 & 3 F.
„ sp.	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.

SPECIES.	Found also in Lower Cretaceous.	Lower Gault. Mammillatus Zone.	Lower Gault. Lower Gault Clays.	Zone of Amm. rostratus. Upper Gault.	Zone of Amm. rostratus. Malmstone and Sands.	Zone of Amm. rostratus. Blackdown and Haldon.	Cambridge Greensand.	Red Chalk.	Zone of Pecten asper. Lower Beds.	Zone of Pecten asper. Chert Beds.	Zone of Pecten asper. Highest Beds.	Range into Chalk.	Gault.	Upper Greensand.	LOCALITIES AND REMARKS.
	*	1	2	3	4	5	6	7	8	9	10	†	g	s	
GASTEROPODA—cont.															
Chemnitzia gaultina, *Gard.*	–	–	2	–	–	–	–	–	–	–	–	–	–	4	2 F. (Pyrgiscus).
,, tenuistriata, *Seeley*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	Do.
,, Woodwardi, *Gard.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl. Do.
Crepidula gaultina, *Buv.*	–	–	–	3	4	–	6	–	–	–	–	–	–	–	3 F. 4 De.
Dentalium acuminatum, *Gard.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
,, alatum, *Gard.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
,, cylindricum, *Gard.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
,, decussatum, *Sow.*	–	–	2	3	4	–	6	–	–	–	–	–	–	–	2 & 3 passim. 4 IW. Pun. SD.
,, divisiense, *Gard.*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 De.
,, *ellipticum* (*see* decussatum															
,, Jeffreysi, *Gard.*	–	–	2	–	–	–	6	–	–	–	–	–	–	–	2 F.
,, medium, *Sow.*	–	–	–	–	4	5	–	–	–	–	–	†	–	–	4 De. 5 Bl. Hl. Sid.
,, sp. (rotomagense ?)	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 M.B.
Dissoketa Meyeri, *Gard.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
Emarginula ancistra, *Gard.*	–	–	–	–	–	–	–	–	–	–	–	s	–	–	s De.
,, divisiensis, *Gard.*	–	–	–	–	–	–	–	–	–	–	–	s	–	–	s De.
,, Gresslyi, *P. & C.*	–	–	–	–	–	–	–	–	–	–	10	s	–	–	s De. ?
Entalis Meyeri, *Gard.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
Funis cancellatus, *Gard.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
,, elongatus, *Seeley*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
Fusus *bilineatus P. & C.* (*see* Murex).															
,, clathratus, *Sow.*	–	–	2	–	4	5	–	–	–	–	–	–	–	–	2 L.R. 4 De. 5 Bl.
,, clementinus, *d'Orb.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	(? = F. Smithi, 3 F.)
,, elegans, *d'Orb*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F. L R.
,, *gaultinus, d'Orb.* (*see* rusticus).															
,, indecisus, *d'Orb.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
,, itierianus, *d'Orb.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
,, quadratus, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl. Sid.
,, quinquecostatus, *Seeley*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	(?=Aporrhais Sanctæ) crucis, P. and C.
,, rigidus, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
,, rusticus, *Sow.*	–	–	2	–	–	5	–	–	–	–	–	–	–	–	(=F. gaultinus, d Orb.) 2 F. L.R. 5 Bl.
,, Smithi, *Sow.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	(Pyrula Smithi) 2 F.
Gibbula (*see* Trochus).															
Littorina carinata, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	s	(Natica) 5 Bl. IW. s IW.
,, conica, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
,, *gracilis* (*see* Cerithium)															
,, crebricostata, *Seeley*	–	–	–	–	–	–	6	–	–	–	?	–	–	–	? 10 War.
,, monilifera, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	(Turbo *Sow*) 5 Bl. Sid.
Murex bilineatus, *P. and C.*	–	–	–	3	–	–	–	–	–	–	10	†	–	–	(Fusus) 3 F. 10 War. Dor.
,, calcar, *Sow.*	–	–	–	3	–	5	–	–	–	–	–	–	–	–	3 F. 5 Bl.
Narica cancellata, *Chem.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
,, carinata, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	(Natica carinata) 5 Bl.
,, cretacea, *d'Orb.*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 Devizes.
,, granosa, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	(Natica.) 5 Bl.
Nassa costellata, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl., Sid.
,, lineata, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
Natica *canaliculata, Sow.* (*see* Genti).															
,, *clementina, d'Orb.* (*see* rotundata).															

SPECIES.	Found also in Lower Cretaceous. *	Lower Gault. Mammillatus Zone. 1	Lower Gault. Lower Gault Clays. 2	Zone of Amm. rostratus. Upper Gault. 3	Zone of Amm. rostratus. Malmstone and Sands. 4	Zone of Amm. rostratus. Blackdown and Haldon. 5	Cambridge Greensand. 6	Red Chalk. 7	Zone of Pecten asper. Lower Beds. 8	Zone of Pecten asper. Chert Beds. 9	Zone of Pecten asper. Highest Beds. 10	Range into Chalk. †	Gault. g	Upper Greensand. s	LOCALITIES AND REMARKS.
GASTEROPODA—cont.															
Natica ervyna, *d'Orb*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
" excavata, *Mich.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
" *gaultina* (*see* Genti).															
" Genti, *Sow.* (=canaliculata, Sow. and gaultina, d'Orb.) (*see* p. 447).	x?	–	2	3	4	5	6	7	–	–	10	–	–	–	2 common. 6 F. 4 De. IW. Ha. 5 Bl. Sid. Hl. 7 H. 10 Dor. (?) derived)
" lavistriata, *Ju.-Br.*	–	–	2	3	–	–	6	–	–	–	–	–	–	–	2 F. 3 F.
" obliqua, *Pric?*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
" Pricei, *de Loriol*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
" rauliniana, *d'Orb.*	–	–	–	–	–	5	6	–	–	–	–	–	–	–	5 Bl. Sld.
" rotundata, *Sow.*	–	–	2	–	–	5	–	–	–	–	–	–	–	–	(Littorina, *see* p. 448). 2 FW. 5 Bl. Sld.
Nerita nodulosa, *Ju.-Br.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
Neritopsis acalaris, *Seeley*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
Phasianella ervyna, *d'Orb.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 & 3 F.
" formosa, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
" pusilla, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
" striata, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl. Sid
" sp.	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl. Hl.
Pileopsis (Capulus) dubia, *Gard.*	–	–	–	–	–	–	–	–	–	–	–	–	g	–	
" seeleyana, *Gard.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
Pleurotomaria allobrogensis? *P. and C.*	–	–	–	–	–	–	6	–	–	–	10	–	–	–	10 War.
" Gibbsi, *Sow.*	–	–	–	3	–	–	6	–	–	–	10	–	–	–	(Pl. gurgitis, d'Orb.) 3 F. 10 Dor. (derived).
" Greppini, *P. & C.*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 Devizes.
" itieriana ?, *P. and Rx.*	–	–	–	3	–	–	6	–	–	–	–	–	–	–	3 F.
" La Harpi, *P. & C.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
" mailleana, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 War.
" perspectiva ?, *Mant.*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 De. Ha.
" regina, *P. & Rx.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
" Rhodani, *Brong.*	–	–	–	–	–	–	6	–	–	–	10	–	–	–	10 War.
" Rouxi, *d'Orb.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
" vraconensis, *P. and C.*	–	–	–	–	–	–	6	–	–	–	?	–	–	–	
" Thurmanni ? *P. and R.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War
" sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
Pteroceras (*see* Aporrhais).															
Pterocerella (*see* Aporrhais).															
Puncturella antiqua, *Gard.*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 Devizes.
Pyrula (?Fusus) Brighti, *Sow.*	–	–	–	–	4	5	–	–	–	–	–	–	–	–	4 De. 5 Bl.
" " depressa, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
" *Smithi, Sow.* (*see* Fusus).															
Pyrgiscus (*see* Chemnitzia.)															
Ringinella lacryma, d'Orb. (*see* Actæon).															
Rissoina incerta, *d'Orb.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
" Sowerbyi, *Gard.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
Rostellaria (*see* Aporrhais).															
Scalaria clementina, *d'Orb.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 & 3 F.
" climaspira, *Gard.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
" dupiniana, *d'Orb.*	x?	–	2	3	4	5	–	–	–	–	–	†	–	–	2 F. BV. N.D. 3 F. 4 De. IW. 5 Bl. Sid.
" Fittoni, *Gard.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl. Sld.
" gaultina, *d'Orb.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
" pulchra, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.

SPECIES.	Found also in Lower Cretaceous.	Lower Gault.		Zone of Amm. rostratus.			Cambridge Greensand.	Red Chalk.	Zone of Pecten asper.			Range into Chalk.	Gault.	Upper Greensand.	LOCALITIES AND REMARKS.
		Mammillatus Zone.	Lower Gault Clays.	Upper Gault.	Malmstone and Sands.	Blackdown and Haldon.			Lower Beds.	Chert Beds	Highest Beds.				
	*	1	2	3	4	5	6	7	8	9	10	†	g	s	
GASTEROPODA—cont.															
Scalaria Queeni, *Gard.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
„ rauliniana, *d'Orb.*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 De.
Siphodentalium affine, *Gard.*	–	–	–	–	–	–	–	–	–	–	–	–	g	–	g F.
„ curvum, *Gard.*	–	–	–	–	–	–	–	–	–	–	–	–	g	–	g F.
Solarium albense, *d'Orb.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F
„ Binghami, *Seeley*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 Dorset.
„ Carteri, *Seeley*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
„ conoideum, *Sow.*	–	–	2	–	–	–	–	–	–	–	–	–	–	s	2 F. s IW.
„ dentatum, *d'Orb.*	–	–	–	3	–	–	6	–	–	–	–	†	–	–	3 F.
„ granosum, *d'Orb.*	–	–	–	–	–	–	?	–	–	–	–	–	–	–	
„ moniliferum, *Mich.*	–	–	2	–	4	5	–	–	–	–	–	–	–	–	2 F. 4 Ha. 5 Bl.
„ ornatum, *Sow.*	–	–	2	3	4	?	6	–	–	–	10	<	–	–	2 & 3 passim. 4 IW. & De. 5 Bl.? 10 War.
„ planum, *Seeley*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
„ rochatianum, *P. & Rx.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
Stomatodon politus, *Seeley*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
Tectura (*see* Acmæa).															
Tessarolax (*see* Aporrhais).															
Tornatella (*see* Actæon).															
Trochus cancellatus, *Seeley*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	(? = Turbo Indecisus, d'Orb.)
„ decussatus, *Leym.*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
„ (Gibbula) levistriata, *Seeley.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
Turbo Brunneri ? *P. and C.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ *monilifera, Sow.* (*see* Littorina).															
„ pictetianus, *d'Orb.*	–	–	–	–	4	–	6	–	–	–	–	–	–	–	(= Turboidea nodosa, Seeley.) 4 De.
„ problematicus, *P. & Rx.*	–	–	–	–	–	–	–	–	–	–	–	–	–	s	s I.W.
„ sp.	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 De.
„ sp.	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 W.
Turritella angulata, *d'Orb.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
„ costata, *Sow*	–	–	2	–	4	5	–	–	–	–	–	–	–	–	2 F. S. Dor 4 Lul. 5 Bi.
„ granulata, *Sow*	x ?	–	2	–	4	5	–	–	–	–	–	–	–	–	2 F. 4 De. BV. 5 Bl. Hl. Sid.
„ subalternans, *P. & C.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
„ vibrayeana, *d'Orb.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F. BV.
Tylostoma sp.	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
LAMELLIBRANCHIATA.															
Amphidesma tenuistriatum, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl. Sid.
Anatina *simplex* (*see* Thracia).															
„ sp.	–	–	2	–	4	–	–	–	–	–	–	–	–	–	2 BV. 4 Dev.
„ sp. (cf. royana, *d'Orb.*)	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 De.
Anomia convexa, *Sow.*	*	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War.
„ lævigata, *Sow.*	*	–	–	–	4	–	–	–	–	–	10	–	–	–	4 De.
„ subtruncata, *d'Orb.*	–	–	–	–	4	–	–	–	–	–	10	–	–	–	4 De. 10 War.
„ transversa, *Seeley*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
„ sp. 1	–	–		–	–	–	–	–	–	–	–	–	–	–	2 F.
„ sp. 2	–	–		–	–	–	–	–	–	–	–	–	–	–	2 F.
Arca echinata, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 Lul.
„ Galliennei, *d'Orb.*	–	–	–	–	4	–	–	–	–	–	(?)	–	–	–	4 De. 10 ? N. Dor.
„ hugardiana, *d'Orb.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	2 F. 3 F.
„ *ligeriensis* ?, *d'Orb.* (*see* passyana).															
„ marullensis, *d'Orb.*	–	–	2	3	–	–	6	–	–	–	–	–	–	–	2 F. 3 F.

SPECIES.	* Found also in Lower Cretaceous.	Lower Gault. 1 Mammillatus Zone.	Lower Gault. 2 Lower Gault Clays.	Zone of Amm. rostratus. 3 Upper Gault.	Zone of Amm. rostratus. 4 Malmstone and Sands.	Zone of Amm. rostratus. 5 Blackdown and Haldon.	6 Cambridge Greensand.	7 Red Chalk.	Zone of Pecten asper. 8 Lower Beds.	Zone of Pecten asper. 9 Chert Beds.	Zone of Pecten asper. 10 Highest Beds.	† Range into Chalk.	g Gault.	s Upper Greensand.	LOCALITIES AND REMARKS.
LAMELLIBRANCHIATA–cont.															
Arca passyana, *d'Orb.*		–	–	–	4	5	–	–	–	–	10	†	–	–	4 De. 5 Hl. 10 Lul.
„ pholadiformis, *d'Orb.*	–	–	–	–	4	–	–	–	–	–	10	–	–	–	4 De. 10 Dor.
„ Raulini ?, *d'Orb.*	*	–	2	–	–	–	–	–	–	–	–	–	–	–	2 W.
„ rotundata, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Hl. Bl.
„ serrata?, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 Dor.
(*See also* Cucullæa·)															
Arcopagia (*see* Tellina (Linearia)															
Astsrte concinna, *Sow.*	–	–	–	–	4	5	–	–	–	–	–	–	–	–	4 Lul. 5 Bl.
„ dupiniana, *d'Orb.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	
„ formosa, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl. Hl.
„ impolita, *Sow.*	–	–	–	–	4	5	–	–	–	–	–	–	–	–	4 Lul. 5 Bl.
„ multiatriata, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
„ omalioides, *Gard., M.S.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ obovata, *Sow.*	*	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl. Hl.
„ striata, *Sow.*	–	–	–	–	4	5	–	–	–	–	–	–	–	–	4 Lul. 5. Bl.
Avicula anomala, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl. Hl.
„ cenomanensis, *d'Orb.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ gryphæoides, *Sow.*	–	–	–	3	4	–	6	7	8	9	10	†	–	–	3, 4 passim. 7 H. Sp. Yo. Li.
„ lanceolata, *Forbes*	–		–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
„ pectinata, *Sow.*	*	–	–	–	4	5	–	–	–	–	–	–	–	–	4 Dor. 5 Bl.
„ rauliniana, *d'Orb.*	–	–	2	3	4	5	–	–	–	–	–	–	–	–	2 IW. 3 F. 4 De. 5 Bl.
Capsa ? elegans, *d'Orb.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl. Hl.
Cardita Constanti, *d'Orb.*	–	–	2	–	–	–	–	–	–	9	–	–	–	–	2 IW. 9 IW.
„ cottaldina ?, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 N. Dor.
„ dupiniana, *d'Orb.*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 Lul. Ha.
„ rotundata, *Pict.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. ·3 (Bed 8 F.).
„ tenuicosta, *Sow.*	–	–	2	3	4	–	6	–	–	–	(?)	–	–	–	2 F. 3 F. 4 IW. 10 ? Dor.
„ dubia ? *d'Orb*	–	–	–	–	–	–	–	–	8	–	10	–	–	–	8 Lul. 10 Dor.
Cardium alutaceum, *Münst.*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 Dor.
„ *decussatum* (*see* Pholadomya)															
„ gentianum, *Sow*		–	–	–	4	–	–	–	–	–	10	–	–	–	4 De. IW. BV. 10 N.D. (? derived).
„ hillanum, *Sow*	–	–	–	–	4	5	–	–	–	–	–	–	–	–	4 De. IW. Dev. Dor. 5 Bl. Sid. Hl. IW.
„ proboscideum, *Sow*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl. Hl.
„ spheroideum, *Forbes*	–	–	–	–	–	–	–	–	8	–	–	–	–	–	8 Wilts.
„ subhillanum, *Leym.*	*	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
„ *tuberculatum, Sow.* (*see* C. gentianum).															
„ ventricosum, *d'Orb.*	–	–	–	–	–	–	–	–	8	–	–	–	–	–	8 Lul.
„ raulinianum ?, *d'Orb.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 Wilta.
Corbis gaultina, *P. and R.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
„ sp.	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 N.D.
„ sp.	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 De.
Corbula elegans, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl. Hl. Sld.
„ gaultina, *P. and C.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F. BV.
„ *gigantea, Sow.* (*see* Thetis).															
„ striatula, *Sow*	*	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
„ truncata, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl. Sid.
Crassatella regularis ?, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War.
„ (like Guerangeri), *d'Orb.*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 De.
Cucullæa æquilateralis, *C. & Br.*	–	–	–	–	4	–	–	–	–	–	10	–	–	–	4 Lul. 10 Dor.
„ carinata, *Sow.*	–	1	2	3	4	5	–	–	–	–	–	–	–	–	1 F. 2, 3, 4 passim 5 Bl. Hl. Sid.
„ *formosa, Sow.* (*see* venusta).															
„ glabra, *Sow.* (= fibrosa)	–	–	2	3	4	5	6	–	–	–	–	–	–	–	2 W 3 F. 4 passim. 5 Bl. Sid. Hl.

SPECIES.	Found also in Lower Cretaceous. *	Lower Gault. Mammillatus Zone. 1	Lower Gault. Lower Gault Clays. 2	Zone of Amm. rostratus. Upper Gault. 3	Zone of Amm. rostratus. Malmstone and Sands. 4	Zone of Amm. rostratus. Blackdown and Haldon. 5	Cambridge Greensand. 6	Red Chalk. 7	Zone of Pecten asper. Lower Beds. 8	Zone of Pecten asper. Chert Beds. 9	Zone of Pecten asper. Highest Beds. 10	Range into Chalk. †	Gault. g	Upper Greensand. s	LOCALITIES AND REMARKS.
LAMELLIBRANCHIATA–cont.															
Cucullæa mailleana, *d'Orb.*	–	–	–	–	–	–	–	–	–	9	10	†	–	–	9 IW. 10 Dor. IW.
„ nana, *d'Orb.*	–	–	2	3	4	–	6	–	–	–	–	–	–	–	2 F. 3 F. 4 Lul.
„ obesa, *P. and R.*	–	–	–	3	4	–	6	–	–	–	–	–	–	–	3 F. 4 Lul. IW. De.
„ venusta, *Nyst.* (*See also* Arca.)	–	–	–	–	4	5	–	–	–	–	–	–	–	–	4 Lul. Pun. 5 Bl.
Cyprina angulata, *Flem.*	*	–	2	–	4	5	–	–	–	–	–	–	–	a	2 W. 4 De. Dev. 5 Bl. Hl. Sid. s. IW.
„ consobrina, *d'Orb.*	–	–	–	–	–	–	–	–	8	–	–	–	–	–	8 Lul.
„ cuneata, *Sow.*	–	–	–	–	4	5	–	–	–	–	–	–	–	–	4 Dev. 5 Bl. Hl. Sid.
„ quadrata, *d'Orb.*	–	–	–	3	4	–	–	–	–	–	10	†	–	–	3 F. (Bed 8). 4 De. 10 War.
„ regularis, *d'Orb.*	–	–	–	–	4	–	–	–	–	–	–	–	g	–	4 De. g F.
„ rostrata, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl. Hl.
„ sp.	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 I.W. De.
„ truncata, *Sow.*	–	–	2	–	4	–	–	–	–	–	–	–	–	–	2 BV. 4 De.
Cypricardia sp.	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War.
Cytherea caperata, *Sow.*	–	–	–	–	4	5	–	–	–	–	–	–	–	–	4 Lul. IW. Dev. 5 Bl. Hl. Sid.
„ lineolata, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl. Hl.
„ *ovalis, Sow.* (*see* Venus).															
„ parva, *Sow.*	–	–	2	–	4	5	–	–	–	–	–	–	–	–	2 W. 4 Lul. 5 Bl.
„ plana, *Sow.*	–	–	–	–	4	5	–	–	–	–	–	–	–	–	4 De. IW. BV. Dev. S. Dor. 5 Bl. Hl.
„ subrotunda, *Sow.*	–	–	–	–	4	5	–	–	–	–	–	–	–	–	4 Lul. 5 Bl.
„ truncata, *Sow.*	–	–	2	–	4	5	–	–	–	–	–	–	–	–	2 BV. 4 Lul. De. 5 Bl.
Eriphyla (*see* Lucina).															
Exogyra columba, *Lam.*	–	–	–	–	4	–	–	–	8	9	–	–	–	–	4 IW. Dor. Dev. 8 Dor. 2 Dev.
„ conica, *Sow.*	*	–	2	3	4	5	6	7	8	9	10	†	–	–	Common throughout.
„ digitata, *Sow.*	–	–	–	–	–	–	–	–	–	9	10	–	–	s	9 Dev. 10 Dor. s IW.
„ haliotoidea, *Lam.*	*	–	2	3	4	5	6	7	–	9	10	†	–	–	Common throughout.
„ *laciniata* (*see* digitata).															
„ plicata, *Lam.*	*	–	–	–	4	5	–	–	–	–	–	–	–	–	4 De. 5 Bl. Hl.
„ rauliniana, *d'Orb.*	–	–	–	3	4	–	6	7	–	–	–	–	–	–	3 F. 4 IW. 7 Hun., Sp
„ sinuata, *Sow.*	*	1	–	–	–	–	–	–	–	–	–	–	–	–	1 Dor.
„ undata, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
Fimbria (*see* Corbis).															
Gastrochæna pyriformis, *Mant.*	*	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F. (Bed 8).
Gervilla anceps, *Desh.*	*	–	–	–	4	5	–	–	–	–	–	–	–	–	4 IW. 5 Bl. Hl.
„ forbesiana, *R. B. Newt.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 N.D.
„ linguloidea, *Forbes*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 BV.
„ rostrata, *Sow.*	–	–	–	–	4	5	–	–	–	–	–	–	–	–	4 ? De. 5 Bl. Hl.
„ solenoides, *Defr.*	*	–	2	3	–	5	6	–	–	–	–	–	–	–	2 F. Dor. Bd. 3 F. (Bed 8). 5 Bl.
Goniomya vilbersensis ?, *d'Orb.*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 De.
„ sp.	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
Gryphæa vesiculosa (*see* Ostrea).															
Hinnites pectinatus *Seeley (M.S.)*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
„ trilinearis, *Seeley*	–	–	–	–	–	–	6	7	–	–	–	–	–	–	7 Hun.
„ Salteri, *Seeley (M.S.)*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ Studeri, *P. & R.*	–	–	–	3	4	–	6	7	–	–	–	–	–	–	3 F. 7 Hun.
„ sp.	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ sp.	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
Inoceramus concentricus, *Park.*	*?	1	2	3	4	5	6	7	–	–	–	–	–	–	1, 2, 3, passim. 4 Lul. De. Ha. BV. 5 Bl Sid. 7 Hun.

SPECIES.	Found in Lower Cretaceous. *	Lower Gault. Mammillatus Zone. 1	Lower Gault. Lower Gault Clays. 2	Zone of Amm. rostratus. Upper Gault. 3	Zone of Amm. rostratus. Malmstone and Sands. 4	Zone of Amm. rostratus. Blackdown and Haldon. 5	Cambridge Greensand. 6	Red Chalk. 7	Zone of Pecten asper. Lower Beds. 8	Zone of Pecten asper. Chert Beds. 9	Zone of Pecten asper. Highest Bed. 10	Range into Chalk. †	Gault. g	Upper Greensand. s	LOCALITIES AND REMARKS.
LAMELLIBRANCHIATA-cont.															
Inoceramus Crispi, *Mant.*	–	–	–	3	–	–	–	7	–	–	–	–	–	–	3 F. 7 Hun. Sp.
" latus, *d'Orb.* non *Mant.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War. Mel.
" propinquus, *Goldf.*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 IW.
" Salomoni, *d'Orb.*	–	1	–	–	–	–	–	–	–	–	–	–	–	–	1 F.
" subsulcatus, *Wiltsh.*	–	–	–	3	–	5	–	–	–	–	–	–	–	–	3 F. 5 Bl.
" sulcatus, *Park*	–	–	2	3	4	5	6	7	–	–	–	–	–	–	2 W. Bu. Bd. Nor. 3 K.R. 4 Lul. Dev. 5 Bl. Sid. 7 Hun. Sp. Yo.
" tenuis, *Mant.*	–	–	2	–	–	–	–	7	–	–	–	–	–	–	2 Bd. ? 7 Hun. Sp. Li.
Isoarca Agassizi, *P. & R.*	–	–	–	–	4	–	6	–	–	–	–	–	–	–	4 De.
Isocardia *crassicornis, d'Orb.* (*see* Isoarca Agassizi).															
" cryptoceras, *d'Orb.*		–	–	–	4	–	–	–	–	–	–	–	–	–	4 De. (Barrois).
Janira (*see* Pecten and Neithea).															
Leda (*see* Nuculana).															
Lima albensis ?, *d'Orb.*	–	–	–	–	4	–	–	–	–	–	10	–	–	–	4 De. 10 War.
" archiaciana, *C. & Briart.*	–	–	–	–	4	–	–	–	–	–	10	–	–	–	4 De. IW. (Barrois). 10 Lul.
" astieriana, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 Lul
" cenomanensis, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War.
" Galliennei, *d'Orb.*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 De.
" globosa, *Sow.*	–	–	2	3	4	–	6	7	–	–	–	†	–	–	2 F. 3 F. 4 Ha. 7 Hun.
" intermedia, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	—
" interlineata, *J. Br.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
" itieriana, *P. & R.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
" moreana ?, *d'Orb.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
" ornata, *d'Orb.*	–	–	–	–	–	–	–	–	–	9	10	–	–	–	9 IW. 10 Dor.
" parallela, *d'Orb* (non *Sow.*)	–	–	2	3	4	–	–	–	–	–	–	–	–	–	2 F. W. IW. Dor. 3 F. 4 De. Ha.
" rauliniana, *d'Orb.*	–	–	–	–	4	–	6	–	–	–	–	–	–	–	4 IW.
" rotomagensis, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War.
" semiornata, *d'Orb.*	–	–	–	–	–	–	–	–	–	9	10	†	–	–	9 IW. 10 War. Dor.
" semisulcata, *Sow.*	*?	–	–	–	4	5	–	–	8	9	10	†	–	–	4 De. Dev. 5 Bl. 8 Dor. War. 9 passim.
" subovalis, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
" new sp.	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 De.
Limopsis sp.	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
" Lorioli ?, *Ren.*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 Lul.
Lithodomus sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	—
Lucina lenticularis ?, *Goldf.*	–	–	2	–	4	–	–	–	–	–	–	–	–	–	2 Dor. 4 De. Lul. Dor.
" orbicularis, *Sow.*	–	–	–	–	4	5	–	–	–	–	–	–	–	–	4 Dev. 5 Bl. Hl. Sid.
/ " pisum, *Sow.*	–	–	–	–	4	5	–	–	–	–	–	–	–	–	4 BV. 5 Bl. Sid.
" sculpta, *Phil.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
" tenera, *Sow.*	–	–	2	–	4	–	6	–	–	–	–	–	–	–	2 F. BV. 4 De.
Lutraria (*see* Thracia).															
Mactra angulata, *Sow.*	–	–	–	–	4	5	–	–	–	–	–	–	–	–	4 Lul. 5 Bl. Sid. Hl.
Modiola (like æqualis, *Sow.*)	–	–	–	–	4	5	–	–	–	–	10	–	–	–	4 De. IW. 5 Bl.
" Cottæ, *Roem.*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 N and W. Dor.
" ligeriensis, *d'Orb.*	*	–	–	–	4	5	–	–	–	–	–	–	–	–	4 De. IW. 5 Bl.
" reversa, *Sow.*	–	–	–	–	4	5	–	–	–	9	–	–	–	–	4 IW. Lul. BV. Ha. 5 Bl. Hl. Sid. 9 Hl.
" sp.	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 BV.
Mya (see Pleuromya).															
Myacites (*see* Pleuromya).															

SPECIES.	* Found also in Lower Cretaceous.	Lower Gault. 1 Mammillatus Zone.	2 Lower Gault Clays.	Zone of Amm. rostratus. 3 Upper Gault.	4 Malms one and Sanαs.	5 Blackdown and Haldon.	6 Cambr dge Greessand.	7 R. d Chalk	Zone of Pecten asper. 8 Lower Beds.	9 Chert Beds.	10 Highest Beds.	† Range into Chalk.	g Gault.	s Upper Greenennd.	LOCALITIES AND REMARKS.
LAMELLIBRANCHIATA-cont.															
Mytilus Galliennei, *dOrb.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F. (Bed. 8).
„ inæquivalvis, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
„ prælongus, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
„ siliqua, *Sow.*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 De.
„ striato-costatus, *d'Orb.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
„ subsimplex, *d'Orb*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 N.D.
„ tridens, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl. Hl.
Neithea (*see* Pecten).															
Neæra sabaudiana, *P. & C.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ shnctæ-crucis, *P. & C.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ undulata, *Sow.*	–	–	–	–	–	–	–	–	–	–	–	–	g	–	g F.
Nucula albensis, *d'Orb.*	–	–	2	–	–	–	6	–	–	–	–	–	–	–	2 F.
„ *angulata* (*see* Nuculana).															
„ antiquats, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl. Sid.
„ apiculata (? antiquata)	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Sid.
„ arduennensis, *d'Orb.*	–	–	2	–	–	–	6	–	–	–	–	–	–	–	2 F.
„ bivirgata, *Sow.*	–	–	2	3	–	–	6	–	–	–	–	–	–	–	2 F. IW. BV. 3 E. F. (Bed. 8),
„ „ var. ornatissima, *d'Orb.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ capsæformis, *Mich.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ gaultina, *Gard.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ impressa, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl. Sid.
„ *Mariæ, d'Orb.* (see Nuculana).															
„ obesa	–	–	–	–	–	–	–	–	–	–	10	–	–		10 N.D.
„ obtusa, *Sow.*	–	–	2	–	4	5	–	–	–	–	–	–	–	–	2 F. 4 De. 5 Bl. Hl.
„ ovata, *Sow.*	–	–	2	3	4	–	6	–	–	–	–	–	–	–	2 F. R. BV. 3 F. E. 4 Ds.
„ pectinata, *Sow.*	–	–	2	3	4	5	–	–	–	–	–	–	–	–	2 & 3 passim. 4 De. 5 Bl.]
„ *rhomboidea, Seeley* (see Nuculana vibrayeana).															
„ *subelliptica, Seeley* (see Nuculana vibrayeana).															
„ *vibrayeana, d'Orb.* (see Nuculana).															
Nuculaua angulata, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	(Nucula) 5 Bl.
„ lineata, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	(Nucula) 5 Bl. Hl. Sid.
„ Mariæ, *d'Orb.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	(Nucula) 2 F. 3 F.
„ phassolina, *Mich.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	(Nucula) 2 F.
„ solea, *d'Orb.*	–	–	2	3	4	–	6	–	–	–	–	–	–	–	2 F. 3 F. 4 De.
„ vibrayeana, *d'Orb.*	–	–	2	3	–	–	6	–	–	–	–	–	–	–	[= Nucula subelliptica, Seeley; and N. rhomboidea, Seeley.]
Opis Galliennei ?, *d'Orb.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Hl.
Ostrea canaliculata, *Sow.* (=O. lateralis, Nilss.)	–	–	2	3	4	–	–	7	–	–	10	†	–	–	2 I.W. Dor. 3 F. 4 Lul. Dc. IW, 7 Sp.
„ *carinata, Sow.* (=O. frons)															
„ cunabula, *Seeley*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
„ curvirostrls	–	–	2	–	4	–	–	7	–	–	–	–	–	–	2 Nor. 4 IW. 7 Hun.
„ frons, *Park*	*	–	–	3	4	5	6	7	–	9	10	†	–	–	3 F. 4 De. IW. Lul. 5 Hl. 7 Hun. 9 Dev. 10 N.D.
„ lagena, *Seeley*		–	–	–	–	–	6	–	–	–	–	–	–	–	—
„ *lateralis, Nilss.* (*see* canaliculata.															
„ Leymerii. *Desh.*	*	1	–	–	–	–	–	–	–	–	–	–	–	–	1 Dor.
„ *macroptera* (= O. frons)															—

SPECIES.	Found also in Lower Cretaceous.	Lower Gault. Mammillatus Zone.	Lower Gault. Lower Gault Clays.	Zone of Amm. rostratus. Upper Gault.	Zone of Amm. rostratus. Malmstone and Sands.	Zone of Amm. rostratus. Blackdown and Haldon.	Cambridge Greensand.	Red Chalk.	Zone of Pecten asper. Lower Beds.	Zone of Pecten asper. Chert Beds.	Zone of Pecten asper. Highest Beds.	Range into Chalk.	Gault.	Upper Greensand.	LOCALITIES AND REMARKS.
	*	1	2	3	4	5	6	7	8	9	10	†	g	s	
LAMELLIBRANCHIATA–cont.															
Ostrea vesicularis, *Lam.*	–	–	2	3	4	–	6	7	8	9	10	†	–	–	Common in most places.
„ vesiculosa, *Sow.*	–	–	–	3	4	–	–	7	8	9	10	–	–	–	[*Gryphæa*] 3 ? 4 passim. 7 sp. 8, 9, 10, War. Dor.
„ virgata, *Goldf.*	–	–	–	–	–	–	–	–	–	–	–	–	–	s	s IW.
Panopæa (*see* Pleuromya).															
Pecten acuminatus ?, *Gein.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
„ asper, *Lam.*	–	–	–	–	4	–	–	–	8	9	10	†	–	–	4 Ha. 8 Mel, Dor. 9 Dor. 10 Wilts. IW.
„ Barretti, *Seeley*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
„ Beaveri, *Sow.*	–	–	–	3	–	–	–	7	–	–	–	–	–	–	3 F. 7 Hun., Sp.
„ compositus, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
„ *crispus*, *Roem.* (*see* elongatus).															
„ *depressus*, *Goldf.*, *see* Beaveri, *Sow.*															
„ divaricatus, *Reuss.*	–		–	–	–	5	–	–	–	–	–	–	–	–	[= curvatus, Gein.] 5 Bl. Hl.
„ Dutemplei, *dOrb.*	–		–	3	4	–	–	–	–	–	–	–	–	–	3 F. (Bed. 8). 4 IW. Dev.
„ elongatus, *Lam.* (*see* p. 451).	–	–	–	–	4	–	–	7	8	–	10	†	–	–	4 Ha. 7 Hun. 8 Lul. 10 War.? [elongatus auctorum].
„ like fissicosta, *Eth.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War.
„ Galliennei, *d'Orb.*	–	–	2	–	4	–	–	–	8	9	10	–	–	–	2 N.D. 4 Lul. 8 War. 9 IW. 10 War. Mel Dor.
„ hispidus, *Goldf.*	–	–	–	–	4	–	–	–	–	–	10	†	–	–	4 Lul. I.W. 10 Lul. Mel. N.D.
„ Milleri, *Sow.*	–	–	–	–	4	5	–	–	–	–	10	–	–	–	4 Lul. 5 Hl. 10 Bl. Sid. ? 10 War. Dor.
„ *obliquus*, *Sow.* (*see* elongatus															
„ orbicularis, *Sow.*	–	1	2	3	4	5	6	7	8	9	10	†	–	–	Common throughout.
„ puzosianus, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 War. N.D.
„ raulinianus, *d'Orb.*	–	–	–	3	4	–	6	–	–	–	–	–	–	–	3 F. E. 4 De.
„ rotomagensis, *d'Orb.*	–	–	2	–	–	–	–	–	–	–	10	–	–	–	2 F. 10 War.
„ striato-punctatus, *Roem.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F. (Bed 8).
„ stutchburianus, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
„ (Neithea) atavus, *d'Orb.*	*	1	–	–	–	–	–	–	–	–	–	–	–	–	1 F.
„ „ æquicostatus, *d'Orb.*	–	–	–	–	4	–	–	–	–	–	10	†	–	–	4 Lul. 10 War., Dor.
„ „ alpinus ?, *d'Orb.*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 S. Dor.
„ „ cometa, *d'Orb.*	–	–	–	–	–	–	–	–	8	9	10	†	–	–	8 Mel. 9 IW. 10 War. Dor.
„ „ Morrisi, *P and Ren.*	–	1	–	–	–	–	–	–	–	–	–	–	–	–	1 F.
„ „ quadricostatus, *Sow.*	–	–	2	3	4	5	6	7	8	9	10	†	–	–	Common everywhere from 2 to 10.
„ „ quinquecostatus *Sow.*	–	–	2	3	4	5	6	7	8	9	10	†	–	–	Common everywhere from 2 to 10.
Pectunculus sublævis, *Sow.*	–	–	2	–	–	5	–	–	–	–	10	–	–	–	2 F. 5 Bl. Hl. 10 N.D.
„ umbonatus, *Sow.*	–	–	2	–	4	5	–	–	–	–	–	–	–	–	2 F. W. 4 S. Dor. Dev. 5 Bl. Hl.
Periploma (*see* Neæra & Thracia)															
Perna lanceolata, *Gein*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
„ lissa, *Seeley*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ oblonga, *Seeley*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
„ rauliniana, *d'Orb.*	–	–	2	–	–	–	6	–	–	–	–	–	–	–	2 F.
„ ricordeana, *d'Orb.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ rostrata, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
„ semielliptica, *Seeley*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	

SPECIES.	Found also in Lower Cretaceous.	Lower Gault.		Zone of Amm. rostratus.			Cambridge Greensand.	Red Chalk.	Zone of Pecten asper.			Range into Chalk.	Gault.	Upper Greensand.	Localities and Remarks.
		Mammillatus Zone.	Lower Gault Clays.	Upper Gault.	Malmstone and Sands.	Blackdown and Haldon.			Lower Beds.	Chert Beds.	Highest Beds.				
	*	1	2	3	4	5	6	7	8	9	10	†	g	s	
LAMELLIBRANCHIATA–cont.															
Perna subspathulata, *Reuss*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
„ transversa, *Seeley*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ sp.	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 De.
Petricola ? canaliculata *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
„ nuciformis, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
Pinna decussata ?, *Goldf.*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 De.
„ Reynesi, *Heb. & M.-Ch.*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 IW.
„ tetragona, *Sow.*	*	–	2	–	4	5	–	–	–	–	–	–	–	–	2 F. BV. Lul. 4 De. BV. 5 Bl.
„ tegulata ?, *Eth.*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 Ha.
Pholadomya decussata, *Phil.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	(Cardium) 2 F.
„ „ var. triangularis, *Seeley.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
„ fabrina	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. N.D. BV. 3 F.
„ sp.	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 De.
Pholadidea constricta, *Phil.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F. (Bed 8).
„ Rhodani, *P. & C.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F. (Bed 8).
„ sanctæ-crucis, *P. & C.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F. (Bed 8).
„ sp. nov.	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F. (Bed 8).
„ sp.	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 Nor.
Pleuromya læviuscula, *Sow.*	–	–	–	–	4	5	–	–	–	–	–	–	–	–	4 Pun. Lul. 5 Bl. Sid.
„ mandibula, *Sow.*	*?	–	2	–	4	–	–	–	–	–	–	–	–	–	2 W. Dor. 4 De. IW. BV.
„ ovalis, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
„ plicata, *Sow.*	*	1	2	–	4	5	–	–	–	–	–	–	–	–	1 Dor. 2 W. IW. Dor. 4 De. BV. 5. Bl.
„ Rhodani, *P. & R.*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 Lul. De. (Barrois).
Plicatula pectinoides, *Sow.*	*	–	2	3	4	5	6	7	–	–	10	†	–	–	Common everywhere in 2 to 6. 7 Sp. 10 Dor.
„ inflata, *Sow.*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 N.D.
„ minuta, *Seeley*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ sigillina, *Woodw.*	–	–	2	3	–	–	6	7	–	–	–	–	–	–	2 & 3 common. 7 Hun.
Psammobia gracilis, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
Siliqua ? moreana, *d'Orb.*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 Lul. De.
Solecurtus sp.	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 De.
Solen ? Dupinianus	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 BV. I.W. Dor.
Sphæra (see Corbis).															
Spondylus gibbosus, *d'Orb.*	–	–	–	3	4	–	6	7	–	–	–	–	–	–	3 F. Bu. 4 Ha. 7 Hun. Sp. Ll.
„ hystrix, *Goldf.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
„ Omali, *d'Arch.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 Dor.
„ striatus, *Sow.*	–	–	–	–	–	5	–	7	–	9	10	†	–	–	5 Hl. 7 Hun. Sp. 9 IW. 10 War. Dor.
Tellina inæqualis, *Sow.*	*	–	–	–	4	5	–	–	–	–	–	–	–	–	4 De. IW. BV. 5 Bl. Hl. Sid.
„ phaseolina, *Phil.*	–	–	2	–	–	–	6	–	–	–	–	–	–	–	2 F.
„ striatula, *Sow.*	–	–	–	–	4	5	–	–	–	–	10	–	–	–	4 De. Dev. 5 Bl. Hl. Sid. 10 N. Dor.
„ (Linearia) rauliniana, *d'Orb.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
Teredo argonensis, *Buv.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ sp.	–	–	2	–	–	–	6	–	–	–	–	–	–	–	2 F.
Thetis genevensis, *P. & R.*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 Lul.
„ gigantea, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Hl.
„ lævigata, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	
„ Sowerbyi, *Roemer* (=major and minor, Sow.).	*	–	2	3	4	5	–	–	–	–	–	–	–	–	2 F. 3 F. 4 passim 5 Bl. Sid.
Thracia sancta-crucis, *P. & C.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.

SPECIES.	Found also in Lower Cretaceous. *	Lower Gault. Mammillatus Zone. 1	Lower Gault. Lower Gault Clays. 2	Zones of Amm. rostratus. Upper Gault. 3	Zones of Amm. rostratus. Malmstone and Sands. 4	Zones of Amm. rostratus. Blackdown and Haldon. 5	Cambridge Greensand. 6	Red Chalk. 7	Zones of Pecten asper. Lower Beds. 8	Zones of Pecten asper. Chert Beds. 9	Zones of Pecten asper. Highest Beds. 10	Range into Chalk. †	Gault g	Upper Greensand. s	Localities and Remarks.
LAMELLIBRANCHIATA–cont.															
Thracia simplex, *d'Orb.*	–	–	2	–	–	–	–	–	–	–	–	–	g	–	[Periploma] 2 Dor. g F.
„ sp.	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 De.
Trigonia affinis, *Sow.*	–	–	–	–	4	5	–	–	–	–	–	–	–	–	4 Dev. 5 Bl. Hl.
„ aliformis, *Park.*	–	–	2	–	4	5	–	–	–	–	–	–	–	–	2 Dor. 4 De. IW. Lul. Dev. 5 Bl. Hl. Sid.
„ „ var. attenuata, *Lyc.*	–	–	–	–	4	–	–	–	–	–	10	–	–	–	4 De. IW. Lul 10 War. Dor.
„ archiaciana, *d'Orb.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 Dor.
„ carinata, *Ag.*	*	–	–	–	4	–	–	–	8	–	10	–	–	–	4 IW. De. 8 Mel. 10 Dor.
„ crenulifera, *Lyc.*	–	–	–	–	4	–	–	–	–	–	10	†	–	–	4 De. ? (*see* Lycett). 10 War. N.D. Dev.
„ Cunningtoni, *Lyc.*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 De.
„ dædalea, *Park.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl. Hl.
„ *excentrica, Park.* (*see* affinis).															
„ Fittoni, *Desh.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F. W. Dor.
„ *hunstantonensis* (*see* scapha).															
„ læviuscula, *Lyc.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl. Sid.
„ pennata, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	†	–	–	5 Hl.
„ pyrrha ?, *d'Orb.*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 Lul.
„ scabricola, *Lyc.*	–	–	–	–	4	5	–	–	–	–	10	–	–	–	4 passim. 5 Bl. Hl. Sid. 10 Lul.
„ scapha, *Ag.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ *sinuata, Park.* (*see* affinis).															
„ spectabilis, *Sow.*		–	–	–	4	5	–	–	–	–	–	–	–	–	4 Dev. 5 Bl. Hl. Sid.
„ spinosa, *Park.*	–	–	–	–	4	5	–	–	–	–	–	–	–	–	4 Lul. De. IW. 5 Bl. Sid.
„ „ var. subovata, *Lyc.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 Dor.
„ sulcataria, *Lam.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Hl.
„ vicaryana, *Lyc.*	–	–	–	–	4	5	–	–	–	–	10	†	–	–	4 IW. 5 Hl. 10 Dor
Unicardium ringmeriense, *Mant.*	–	–	–	–	4	–	–	–	–	–	10	†	–	–	4 De. 10 ? Dor.
Venus faba, *Sow.*	–	–	–	–	4	5	–	–	–	–	–	–	–	–	4 Lul. De. 5 Bl.
„ immersa, *Sow.*	–	–	–	–	4	5	–	–	–	–	–	–	–	–	4 Lul. BV. IW. Dev 5 Bl.
„ ovalis, *Sow.*	–	–	–	–	4	5	–	–	–	–	–	–	–	–	4 De. 5 Bl.
„ rotomagensis ?, *d'Orb.*	–	–	–	–	–	–	–	–	8	–	10	†	–	–	8 Lul. 10 Wilts.
„ sublævis, *Sow.*	–	–	2	–	–	5	–	–	–	–	–	–	–	–	2 BV. 5 Bl. Hl. Sid. (?)
„ submersa, *Sow.*	–	–	–	–	4	5	–	–	–	–	–	–	–	–	4 Lul. 5 Bl.
„ *tenera, Sow.* (*see* Lucina).															
„ *truncata* (*see* Cytherea).															
BRACHIOPODA.															
Argiope megatrema, *Sow*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 War.
Crania cenomanensis, (?) *d'Orb.*	–	–	–	–	–	–	–	7	8	–	–	†	–	–	7 H. 8 IW.
„ sp.															
Lingula subovalis, *Dav.*	–	–	2	–	4	–	–	–	–	–	10	–	–	–	2 Dor. 4 IW. Ha 10 War.
Kingena lima, *Defr.*	–	–	2	3	4	–	6	7	–	–	10	†	–	–	2 Nor. 3 F. 7 H. Sp. Li. 10 War. Chard.

SPECIES.		Lower Gault.		Zone of Amm. rostratus.					Zone of Pecten asper.						LOCALITIES AND REMARKS.
	Found also in Lower Cretaceous. *	Mammillatus Zone. 1	Lower Gault Clays. 2	Upper Gault. 3	Malmstone and Sands. 4	Blackdown and Haldon. 5	Cambridge Greensand. 6	Red Chalk. 7	Lower Beds. 8	Chert Beds. 9	Highest Bed. 10	Range into Chalk. †	Gault. g	Upper Greensand. s	
BRACHIOPODA—cont.															
Rhynchonella *Carteri, Dav.* (*see* lineolata)															
„ *compressa, Lam.* (*see* dimidiata).															
„ dimidiata, *Sow.*	–	–	–	–	4	5	–	–	8	–	10	†	–	–	4 IW. 5 Bl. Hl. 8 IW. 10 De. War. Dor. Chard, Dev.
„ „ var. convexa, *Sow.*	–	–	–	–	4	–	6	–	8	–	10	†	–	–	4 IW. 8 IW. 10 War. Dor. Chard.
„ grasiana *d'Orb.* -	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 War. Dor. Chard.
„ lineolata *Phil.*															—
var. Carteri. Dav.	–	–	–	–	–	–	–	7	–	–	10	†	–	–	7 Hun. Li. Sp.
„ mantelliana, *Sow.*	–	–	–	–	–	–	–	–	–	–	?10	†	–	–	?10 War. N. Dor.
„ Martini, *Sow.* -	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War.
„ parvirostris, (?) *Sow.*	*	–	–	–	4	–	–	–	–	–	–	–	–	–	4 IW.
„ Schlœnbachi, *Dav.*	–	–	–	–	–	5	–	–	–	9	10	–	–	s	5 Bl. 9 Dev. 10 passim. s. IW.
„ sulcata, *Park.* -	*	–	2	3	–	–	6	7	–	–	?10	–	–	–	2 F. 3 E.? 7 Sp. Yo. ?10 War.
Terebratella Beaumonti, *d'Arch.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 Dor.
„ Menardi, *d'Orb.* -	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 Dor.
„ pectita, *Sow.* -	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 IW. War. Dor. Chard, Dev.
Terebratula arcuata, *Roemer* -	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 Dor. (= rugulosa).
„ biplicata, *Sow.* -	–	–	2	3	4	–	–	7	–	–	10	–	–	–	2 W. Bu. Be. Nor. 3 F. 4 De. IW. 7 passim. 10 Mel. N.D.
„ „ var. dutempleana, *d'Orb.*	–	–	2	3	4	–	6	7	–	–	–	–	–	–	2 Bn. Bd. 3 F. 4 De. 7 Hun. Sp.
„ var. obtusa, *Sow.*	–	–	2	3	–	–	6	–	–	–	–	–	–	–	2 Bn. Bd.
„ capillata, *d'Arch.*	–	–	–	–	?	–	–	7	–	–	–	–	–	–	?4 Ha. 7 Hun. Yo. Sp. Li.
„ *lacrymosa,* d'Orb. (*see* ovata)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	—
„ moutoniana, *d'Orb.*	*	1	–	–	–	–	–	–	–	–	–	–	–	–	1 F.
„ obesa, *Sow.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War.
„ ovata, *Sow.* -	–	–	–	–	4	–	–	–	–	–	10	–	–	–	4 De. IW. 10 War. Dor. Mel. Chard.
„ phaseolina ? *Lam.* -	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 ?IW.
„ *rugulosa, Morris* - (*see* arcuata)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	—
„ semiglobosa, *Sow.* -	–	–	–	–	–	–	–	7	–	–	10	–	–	–	7 Hun. Yo. Sp. Li. 10 Dor. Chard.
„ squamosa, *Mant.* -	–	–	–	–	4	–	–	–	–	–	10	–	–	–	4? De. 10 War. De. Dor.
„ sulcifera, *Mor.* -	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun. Yo. Sp.
Terebratulina striata, *Wahl.* -	*	–	–	–	–	–	–	7	–	–	10	†	–	–	7 Sp. 10 War. Mel. Dor.
„ triangularis, *Eth.*	–	–	2	–	–	–	–	7	–	–	10	†	–	–	2 Nor. 7 Hun. Sp. Yo. 10 War. Lul.
Terebrirostra lyra, *Sow.* -	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War. M.B. Dor. Chard, Dev.
Waldheimia, like Juddi, *Walk.* -	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War. Som.
„ tamarindus, *Sow.* -	*	1	–	–	–	–	–	–	–	–	–	–	–	–	?1 Bu.
POLYZOA.															
Apsendesia collis, *d'Orb.* -	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 H.
„ papyracea, *d'Orb.* -	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 H.
Bidiastopora lamellosa, *d'Orb.* -	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War.

SPECIES.	Found also in Lower Cretaceous.	Lower Gault.		Zone of Amm. rostratus.			Cambridge Greensand.	Red Chalk.	Zone of Pecten asper.			Range into Chalk.	Gault.	Upper Greensand.	LOCALITIES AND REMARKS.
		Mammillatus Zone.	Lower Gault Clays.	Upper Gault.	Malmstone and Sands.	Blackdown and Haldon.			Lower Beds.	Chert Beds.	Highest Beds.				
	*	1	2	3	4	5	6	7	8	9	10	†	g	a	
POLYZOA—cont.															
Cellulipora ornata (see Radiopora).															
Ceriopora polymorpha, *Goldf.*	–	–	–	–	4	–	–	–	–	–	10	–	–	a	4 De. 10 War.
„ gracilis, *Goldf.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
Choristopetalon impar, *Lons.*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	—
Desmepora semicylindrica, *Lons.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 N. Dor.
Diastopora clementina, *d'Orb.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
„ cretacea ?, *Vine*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
„ fæcunda, *Vine*	–	–	–	–	–	–	6	7	–	–	–	–	–	–	7 H.
„ Hagenowi, *Reuss*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
„ hunstantonensis, *Vine*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 H.
„ Jessoni, *Vine*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 H.
„ megalopora, *Vine*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
„ papillosa, *Reuss,*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 H.
„ radians ?, *Novak*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 H.
„ regularis, *d'Orb.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ Sowerbyi, *Lonsd.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War.
„ tubulus ?, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War.
Entalophora cenomana, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War.
„ gigantopora, *Vine*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
„ proboscidea, *Edw.*	–	–	–	–	–	–	6	7	–	–	–	–	–	–	7 Hun.
„ ramosissima, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War.
Epidictyon plumatus, *Lonsd.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
Heteropora cryptopora, *Goldf.*	–	–	–	–	–	5	–	7	–	–	–	–	–	–	5 Bl. 7 Hun.
„ dichotoma, *Blainv.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
„ Francquana, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War.
„ irregularis, *d'Orb.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
Membranipora dumerilla, var. cantabrigiensis, *Vine*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
„ fragilis, *d'Orb.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ gaultina, *Vine*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ obliqua, *d'Orb.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
Microporella antiqua, *Vine*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
Multicrescis mammillata, *d'Orb.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ variabilis, *d'Orb.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
Petalopora pulchella, *Lonsd.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 De.
Proboscina augustata, *d'Orb.*	–	–	–	–	–	–	6	7	–	–	–	–	–	–	7 Hun.
„ bohemica, *Novak.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ dilatata, *d'Orb.*	–	–	–	–	–	–	6	7	–	–	–	–	–	–	7 Hun. Sp.
„ gigantopora, *Vine*	–	–	–	–	–	–	6	7	–	–	–	–	–	–	7 Hun.
„ gracilis, var. Reussi, *Vine.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ hunstantonensis, *Vine.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ inornata, *Vine*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ irregularis, *Vine*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ Jessoni, *Vine*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ ramosa, *d'Orb.*	–	–	–	–	–	–	6	7	–	–	–	–	–	–	7 Hun.
„ rugosa ?, *d'Orb.*	–	–	–	–	–	–	6	7	–	–	–	–	–	–	7 Hun.
„ subelegans, *d'Orb.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ toucasiana, *d'Orb.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ uberrima, *Vine*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
Pustulipora pustulosa, *Goldf.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 N.D.
Radiopora bulbosa, *d'Orb.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl. Hl.
„ pustulosa, *d'Orb.*	–	–	–	–	4	–	–	–	–	–	10	–	–	–	4 De. 10 War.
„ ornata, *d'Orb.*	–	–	–	–	–	–	–	–	8	9	10	–	–	–	8 Dev. 9 Dev. 10 N. Dor.

SPECIES.	Found also in Lower Cretaceous. *	Lower Gault. Mammillatus Zone. 1	Lower Gault. Lower Gault Clays. 2	Zone of Amm. rostratus. Upper Gault. 3	Zone of Amm. rostratus. Malmstone and Sands. 4	Zone of Amm. rostratus. Blackdown and Haldon. 5	Cambridge Greensand. 6	Red Chalk. 7	Zone of Pecten asper. Lower Beds. 8	Zone of Pecten asper. Chert Beds. 9	Zone of Pecten asper. Highest Beds. 10	Range into Chalk. †	Gault. 5	Upper Greensand. s	LOCALITIES AND REMARKS.
POLYZOA—cont.															
Reptomulticava collis, *d'Orb.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ mammilla. *Reuss.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ simplex, *d'Orb.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ radiata, *Vine*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
Stomatopora divaricata, *Roem.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ gracilis, *Edw.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ „ var. delicatula, *Vine.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ graciliformis, *Vine*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
„ granulata, *Edw.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ linearis, *d'Orb.*	–	–	–	–	–	–	6	7	–	–	–	–	–	–	7 Hun.
„ longiscata, *d'Orb.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ ramea, *Blainv.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ variabilis, *Vine*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun
Truncatula pinnata, *Röm.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War.
Reptomulticlausa papularia, *Mich*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 N. Dor.
Zonopora irregularis. *d'Orb.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ undata, *d'Orb.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun.
„ variabilis, *d'Orb.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun
CRUSTACEA.															
Decapoda.															
Cyphonotus incertus, *Carter*	–	–	–	–	–	–	6	–	–	–	10	–	–	–	10 War
Diaulax carteriana, *Bell*	–	–	–	3	–	–	6	–	–	–	–	–	–	–	3 F.
„ feliceps, *Woodw.*															
Enoploclytia sp.	–	–	–	–	–	–	–	–	–	–	–	–	g	–	g F.
Etyus Martini, *Mant.*	–	–	2	3	–	–	6	–	–	–	–	–	–	–	2 F. Ring. 3 F.
„ similis, *Bell*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
Eucorystes Carteri, *Bell*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
Glyphæa cretacea, *McCoy*	–	–	–	–	–	–	6	–	–	–	–	†	g	–	g F.
„ Carteri, *Bell*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
Hemioön Cunningtoni, *Bell*	–	–	–	–	–	–	6	–	–	–	10	–	–	–	10 War.
Homolopsis Edwardsi, *Bell*	–	–	–	–	–	–	6	–	–	–	–	–	g	–	g F.
Hoploparia longimana, *Sow.*	*	–	2	3	4	–	–	–	–	–	–	–	–	–	2 F. 3 F. 4 LR.
„ granulosa, *Bell*	–	–	–	–	4	–	–	–	–	–	10	–	–	–	4 Dc. 10 War.
„ minima, *Price* (M.S.)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ punctulata, *Bell*	–	–	–	–	–	–	–	–	–	–	–	–	g	–	—
„ Saxbyi, *McCoy*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 IW. De.
„ scabra, *Bell*	–	–	–	–	4	–	6	–	–	–	10	–	g	–	4 De. g F. 10 (?) W.
„ sulcirostris, *Bell*	–	–	–	–	–	–	6	–	–	–	–	–	g	–	g F.
Mesocrangon atra, *Woodw.*	–	–	–	–	–	–	–	–	–	–	–	–	g	–	—
Necrocarcinus Bechei, *Deslong*	–	–	2	3	–	–	6	–	–	–	10	†	–	–	2 F. R. 3 F. 10 War. MB.
„ glaber, *Woodw.*	–	–	–	–	–	–	–	–	–	9	–	–	–	–	9 M.B.
„ tricarinatus, *Bell*	–	–	2	–	–	–	6	–	–	–	10	–	–	s	2. 10 War. s. Lyme.
„ Woodwardi, *Bell*	–	–	2	–	4	–	6	–	–	–	10	–	–	–	4 Dor. 10 War.
Orithopsis Bonneyi, *Carter*	–	–	–	–	–	–	–	–	–	–	–	–	–	s	s. BV. & Lyme.
Palæocorystes Broderipi, *Mant.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F. Ring.
„ Stokesi, *Mant.*	–	–	2	3	–	–	6	–	–	–	–	–	–	–	2 F. R. 3 F.

SPECIES.	Found also in Lower Cretaceous.	Lower Gault. Mammilatus Zone.	Lower Gault. Lower Gault Clays.	Zone of Amm. rostratus. Upper Gault.	Zone of Amm. rostratus. Malmstone and Sands.	Zone of Amm. rostratus. Blackdown and Haldon.	Cambridge Greensand.	Red Chalk.	Zone of Pecten asper. Lower Beds.	Zone of Pecten asper. Chert Beds.	Zone of Pecten asper. Highest Beds.	Range into Chalk.	Gault.	Upper Greensand.	LOCALITIES AND REMARKS.
	*	1	2	3	4	5	6	7	8	9	10	†	g	s	
CRUSTACEA—cont.															
Decapoda—cont.															
Plagiophthalmus oviformis, *Bell*	–		–	–	–	–	–	–	–	–	10	†	–	–	10 War.
Phlyctisoma granulatum, *Bell* -	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
„ tuberculatum, *Bell*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
„ sp. - - - -	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 Ha.
Podopilumnus Fittoni, *McCoy* -	–	–	–	–	4		–	–	–	–	–	–	–	–	4 LR.
Scillaridea cretacea, *Seeley* (M.S.)	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
„ Gardneri, *Woodw.* -	–	–	–	–	–		–	–	–	–	–	–	g	–	—
„ punctata, *Woodw.* -	–	–	–	–	–	–	–	–	–	–	–	–	g	–	—
Squilla McCoyi, *Seeley* (M.S.)	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
Trachynotus sulcatus, *Bell* -	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War.
Xanthosia gibbosa, *Bell* - -	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War.
„ granulosa, *Bell* - -	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
Cirripedia.															
Pollicipes Bronni, *Roem.* - -	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War.
„ Hausmanni, *K. & D.* -	–	–	–	–	–	–	–	–	–	–	–	–	g	–	g F.
„ lævis, *Sow.* - - -	–	–	2	3	–	5	–	–	–	–	–	†	–	–	2 F. 3 F. E. 5 Bl.
„ rigidus, *Sow.* - -	–	–	2	3	4	–	–	–	–	–	–	–	–	s	2 F. 3 F. 4 De. s. De.
„ unguis, *Sow.* -	*	–	2	3	–	–	–	7	–	–	–	–	–		2 F. 3 F. E. 7 H. Sp.
Scalpellum arcuatum, *Dar.* -	–	–	–	–	–	–	–	–	–	–	–	–	g	–	g F.
„ lineatum, *Dar.* -	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War.
Ostracoda.															
Bairdia harrisiana, *Jones* -	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ subdeltoidea, *Münst* -	–	–	–	3		–	–	–	–	–	10	–	–	–	3 F. 10 War.
Bythocypris reussiana, *J. & H.*	–	–	–	–	–	–	–	–	–	–	–	–	g	–	g F.
„ silicula, *Jones* -	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ var. minor., *J. & H.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
Cythere harrisiana, *Jones* -	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. BV. 3 F.
„ „ var. setosa, *J. & H.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ „ var. reticosa, *J. & H.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ gaultina, *Jones* - -	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ lineato-punctata, *C. & S.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ koninckiana, *Bosq.* -	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ spinifera, *C. & S.* - -	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
Cythereis auriculata, *Corn.* -	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ excavata, *C. & S.* -	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ lonsdaleana, *Jones* -	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ ornatissima, *Reuss* -	–	–	2	3	–	–	–	–	–	–	10	–	–	–	2 F. Go. BV. 3 F. 10 War.
„ „ var, nuda, *J. & H.* - -	–	–	–	3	–	–	–	–	–	–	–	–	–	–	2 Go. BV. 3 F.
„ „ var. paupera, *J. & H.* -	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ „ var. reticulata *J. & H.* -	–	–	2	3	–	–					–	–	–	–	2 F. Go. BV. 3 F.
„ „ var. rudispinata *C. & S.*	–	–	2	3	–	–	–	–		–	–	–	–	–	2 F. 3 F.
„ „ var. stricta, *J. & H.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	2 Go. BV. 3 F.

SPECIES.	Found also in Lower Cretaceous.	Lower Gault. Mammillatus Zone.	Lower Gault. Lower Gault Clays.	Upper Gault.	Zone of Amm. rostratus. Malmstone and Sands.	Zone of Amm. rostratus. Blackdown and Haldon.	Cambridge Greensand.	Red Chalk.	Zone of Pecten asper. Lower Beds.	Zone of Pecten asper. Chert Beds.	Zone of Pecten asper. Highest Beds.	Range into Chalk.	Gault.	Upper Greensand.	Localities and Remarks.
	*	1	2	3	4	5	6	7	8	9	10	†	g	s	
CRUSTACEA—cont.															
Ostracoda—cont.															
Cythereis quadrilatera, *Roem.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. Go. BV. 3 F.
„ triplicata, *Roem.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ „ var. lineata, *C. & S.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ vallata, *Jones*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ Wrighti, *J. & H.*, var. aculeata, *C. & S.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
Cytherella ovata, *Roem.*	–	–	2	3	–	–	–	7	–	–	–	–	–	–	2 F. 3 F. 7 Sp.
„ Muensteri, *Roem.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. BV. 3 F.
„ Beyrichi, *Reuss*	–	–	2	3	–	–	–	–	–	–	–	–	g	–	g F.
„ williamsoniana, *Jones*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ „ var. Chapmanni, *J. & H.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F 3 F.
„ „ var. granulosa *Jones*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ „ var. stricta, *J. & H.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ subreniformis, *J. & H.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
Cytheridea perforata, *Roem.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. Go. BV. 3 F.
„ „ var. insignis, *Jones*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ rotundata, *C. & S.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
Cytherura appendiculata, *Jones*	–	–	–	–	–	–	–	–	–	–	–	–	g	–	g F.
Cytheropteron alatum, *Bosq.* var cornutum, *Bosq.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ cuspidatum, *J. & H.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War.
„ concentricum, *Reuss*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ „ var. virgineum, *Jones*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War.
„ folkestoniense, *C. & S.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ umbonatum, *Will.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ „ var. longispinata, *J. & H.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F
Macrocypris muensteriana, *J. & H.*	–	–	–	–	–	–	–	–	–	–	–	–	g	–	g F.
Paracypris gracilis, *Bosq.*	–	–	–	–	–	–	–	–	–	–	–	–	g	–	g F.
„ siliqua, *J. & H.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
Polycope *sp.*	–	–	–	–	–	–	–	–	–	–	–	–	g	–	g F.
Pontocypris attenuata, *Reuss*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ bosquetiana, *J. & H.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ trigonalis, *J. & H.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ triquetra, *Jones*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
Pseudocythere ? simplex, *J. & H.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
ANNELIDA.															
Ditrupa difformis, *Lam.*	–	–	–	–	–	–	–	–	8	9	10	†	–	–	8, 9, 10 War. 10 Lul. N. Dor.
Galeolaria (*see* Serpula).															
Serpula ampullacea, *Sow.*	*	–	–	–	4	5	–	–	–	–	10	†	–	–	4 De. 5 Bl. 10 War.
„ annulata, *Sow.*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 War.
„ antiquata, *Sow.*	*	–	–	–	4	5	6	7	8	9	10	–	–	–	4 S. Dor. 5 Bl. 7 H. 8, 9,10 War. 10 N. Dor.
„ articulata, *Sow.*	–	–	–	3	–	–	6	–	–	–	–	–	–	–	3 F.
„ carinella, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
„ filiformis, *Sow.*	*	–	2	–	–	5	–	–	–	–	10	†	–	–	2 F. 5 Bl. 10 War.
„ ilium, *Sow.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War., S. Dor.

SPECIES.	Found also in Lower Cretaceous.	Lower Gault. Mammillatus Zone.	Lower Gault. Lower Gault Clays.	Zone of Amm. rostratus. Upper Gault.	Zone of Amm. rostratus. Malmstone and Sands.	Zone of Amm. rostratus. Blackdown and Haldon.	Cambridge Greensand.	Red Chalk.	Zone of Pecten asper. Lower Beds.	Zone of Pecten asper. Chert Beds.	Zone of Pecten asper. Highest Beds.	Range into Chalk.	Gault.	Upper Greensand.	LOCALITIES AND REMARKS.
	*	1	2	3	4	5	6	7	8	9	10	†	g	s	
ANNELIDA—cont.															
Serpula macropus, *Sow*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War.
„ plana ? *Woodw.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War.
„ plexus, *Sow.*	*	–	–	3	4	5	6	–	–	–	10	†	–	–	3 F. 4 De. 5 Bl., Hl. 10 N. Dor.
„ rustica, *Sow.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 H.
„ tuba, *Sow.*	–	–	–	–	–	5	–	–	–	–	10	–	–	–	5 Bl. 10 S. Dor.
„ vermes, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
„ (Vermicularia, *Auct.*) concava, *Sow.*	–	–	–	3	4	5	–	7	8	9	10	–	–	–	3 F. 4 passim. 5 Bl. Hl. Sid. 7. H.S. 8, 9, 10 War. Dor.
„ „ Phillipsi, *Roem.*	–	–	–	–	4	–	–	7	–	–	–	–	–	–	4 IW. 7 S.
„ „ polygonalis *Sow.*	*	–	–	3	4	–	–	–	–	–	–	–	–	–	3 Ay. 4 Lul. Dev.
„ radiata, *Sow.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
„ umbonata ?*Mant.*	–	–	–	–	–	5	–	7	8	9	10	†	–	–	5 Bl. 7 H. Sp. 8, 9. 10 War.
ECHINODERMATA.															
Antedou incurva, *Carp.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
„ paradoxus, *Goldf.*	–	–	–	–	–	5	–	–	–	–	10	–	–	–	5 Bl. 10 War.
Caratomus rostratus, *Ag.*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 War. N.D. S.D. Dev.
Cardiaster fossarius, *Benett.*	–	–	–	–	4	–	–	–	8	9	10	–	–	–	4 De. ? 8, 9 War. MB. 10 War. IW. S.D. WD. M.B.
„ latissimus, *Ag.*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 De. IW. S.D. L.R. S.D.
„ Perezi, *Sism.*	–	–	–		4	5	–	–	–	–	–	–	–	–	4 De. ? 5 Bl.
„ cotteauanne, *d'Orb.*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 Dev.
„ *suborbicularis* (*see* Holaster).	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun. Yo. Sp.
Catopygus columbarius, *Lam.*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	(=C.carinatus,Goldf.) 10 passim.
„ pyriformis, *Goldf.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War.
Cidaris gaultina, *Forbes*	–	–	–	3	–	–	6	7	–	–	–	–	–	–	3 F. E. 7 Hun. Sp.
„ velifera, *Bronn.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War. Lul.
„ vesiculosa, *Goldf.*	–	–	–	–	–	–	–	7	–	–	10	†	–	–	7 H. 10 War. Lul.
„ sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	—
Cottaldia Benettiæ, *Kœnig*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 War. N.D. W.D.
Discoidea subuculus, *Klein*	–	–	–	–	–	–	–	–	8	9	10	†	–	–	8 War. Mel. 9 War. Dor. Hl. 10 Common.
Echinobrissus lacunosus, *Goldf.*	–	–	–	–	–	–	–	–	8	–	10	–	–	–	8 Do. 10 War. N.Do. Chard.
„ Morrisi, *Forbes*	–	–	–	–	–	5	–	–	–	–	10	–	–	–	10 War. Chard.
Echinoconus castaneus, *Brong.*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 War. N.D.
Echinocyphus difficilis, *Ag.*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 War. N.D. S.D.
Echinospatagus murchisonianus, *Mant.*	–	–	–	–	4	5	–	–	–	–	–	–	–	–	4 IW. De. Ha. Dev. 5 Bl.
„ Collagni, *Sism.*	–	–	–	–	–	–	–	–	–	–	–	–	–	s	s Wilts.
„ Quenstedti, *Wright.*	–	–	–	–	4	–	–	–	–	–	–	–	–	–	4 De. IW.
Enallaster Greenovi, *Forbes*	–	–	–	–	4	5	–	–	–	–	–	–	–	–	4 Dev. 5 Bl. Sid.
„ sp.	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
Epiaster Lorioli, *Wright*	–	–	–	–	–	–	–	–	8	9	10	–	–	–	8 War. 9 War. MB. 10 W.D.
Glenotremites (*see* Antedon).															
Glyphocyphus radiatus, *Hon.*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 War. S. D.
Goniaster (? Calliderma) Comptoni, *Forbes*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.
„ „ elegans, *Gray*	–		–	–	–	5	–	–	–	–	–	–	–	–	5 Bl.

SPECIES.	Found also in Lower Cretaceous. *	Lower Gault. Mammillatus Zone. 1	Lower Gault. Lower Gault Clays. 2	Zone of Amm. rostratus. Upper Gault. 3	Zone of Amm. rostratus. Malmstone and Sands. 4	Zone of Amm. rostratus. Blackdown and Haldon. 5	Cambridge Greensand. 6	Red Chalk. 7	Zone of Pecten asper. Lower Beds. 8	Zone of Pecten asper. Chert Beds. 9	Zone of Pecten asper. Highest Beds. 10	Range into Chalk. †	Gault. g	Upper Greensand. s	LOCALITIES AND REMARKS.
ECHINODERMATA.—cont.															
Goniophorus lunulatus, *Ag.*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 War. N.D.
Hemiaster asterias, *Forbes*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ Bailyi, *Forbes*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F. (? = Echinospatagus Murchisonianus).
„ *inæqualis, Forbes,* (*see* Echinospatagus murchisonianus)															
„ MacCoyi, *Seeley*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	? = H. minimus, *Ag.*
„ minimus, *Ag.*	–	–	–	3	–	–	–	–	–	–	10	†	–	–	3 F. 10 War. N. D.
„ *Murchisoniæ, Forbes* (*see* Echinospatagus)															
„ sp. 1	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ sp. 2															
Hemipneustes (*see* Enallaster).															
Holaster lævis, *de Luc,* including var. carinatus	–	–	2	–	4	–	6	–	–	9	10	†	–	–	2 W. 4 De. Ha. IW. 9 War. 10 War N.D. S.D. Dev.
„ obliquus, *Wright*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 War.
„ subglobosus, *Leske*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 War.
„ subglobosus var. altus, *Ag.*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 N.D. Mel.
„ suborbicularis, *Defr.*	–	–	–	–	–	–	–	7	–	–	10?	–	–	–	7 Hun. Sp. 10 ? S.D.
Peltastes clathratus, *Ag.*	–	–	–	–	–	–	–	–	8	–	10	†	–	–	8 Mel. 10 War. N.D. S.D.
„ stellulatus *Ag.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Sp.
„ umbrella, *Ag.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War.
„ Wiltshirei, *Wright*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 H.
Pentacrinus Fittoni, *Austen*	–	–	2	3	–	–	6	7	–	–	–	–	–	–	2 F. 3 F. 7 Hun. Sp.
„ Agassizi, *Hagenow*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 War.
Pseudodiadema Barretti, *Woodw.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
„ Benettiæ, *Forbes*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 War. M.B. N.D.
„ Brongniarti, *Wright,* non *Ag.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 H.
„ Carteri, *Woodw.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
„ Michelini, *Ag.*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	—
„ ornatum, *Goldf.*	–	–	–	3	4	–	6	–	8	–	10	†	–	–	3 F. 4 L.R. 7 H. 8 Mel. 10 S.D.
„ Rhodani, *Ag.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	—
„ variolare, *Ag.*	–	–	–	–	–	–	–	–	?	–	10	†	–	–	8 ? War. 10 War. N.D. S.D.
„ Wiltshirei, *Wright*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
Pygurus lampas, *De la Beche*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 N.D.
Pyrina lævis, *Ag.*	–	–	–	–	–	–	–	–	–	–	?10	–	–	–	10 War. (Wright).
Salenia Desori, *Wright*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War.
„ gibba, *Ag.*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 War. Dev.
„ petalifera, *Desm.*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 War. N.D.
„ Lorioli, *Wright*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War.
„ sp.	–	–	–	–	–	5	6	–	–	–	–	–	–	–	5 Bl.
Torynocrinus rugosus, *Seeley*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Hun. Yo.
ACTINOZOA.															
Actinacis insignis, *Dunc.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Hl.
„ stellulata, *Dunc.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Hl.
Astrocænia decaphylla, *E. & H.*	–	–	–	–	–	5	–	–	–	–	10	–	–	–	5 Hl. 10 War.
Baryhelia reticulata, *Dunc.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Hl.
Barysmilia Cordieri, *E. & H.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Hl.
„ tuberosa, *Reuss.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Hl.
Bathycyathus Sowerbyi, *E. & H.*	–	–	–	3	–	–	6	–	–	–	–	–	–	–	3 F (Bed. viii.)

SPECIES.	* Found also in Lower Cretaceous.	Lower Gault. 1 Mammillatus Zone.	Lower Gault. 2 Lower Gault Clays.	Zone of Amm. rostratus. 3 Upper Gault.	Zone of Amm. rostratus. 4 Malmstone and Sands.	Zone of Amm. rostratus. 5 Blackdown and Haldon.	6 Cambridge Greensand.	7 Red Chalk.	Zone of Pecten asper. 8 Lower Beds.	Zone of Pecten asper. 9 Chert Beds.	Zone of Pecten asper. 10 Highest Beds.	† Range into Chalk.	g Gault.	s Upper Greensand.	LOCALITIES AND REMARKS.
ACTINOZOA.—cont.															
Caryophyllia Bowerbanki, *E. & H.*	–	–	2	3	–	–	–	–	–		–	–	–	–	2 F. 3 F (Bed. viii.)
Ceratotrochus insignis, *Dunc.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
Cyathophora monticularis, *d'Orb.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Hl.
Cyclocyathus Fittoni, *M. E.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
Cyclolites polymorpha, *Goldf.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 H.
Favia minutissima, *Dunc.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Hl.
„ stricta, *M. E.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	(=Parastrea) 5 Bl. Hl.
Haldonia Vicaryi, *Dunc.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Hl.
Heliopora cærulea, *Grimm.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Hl.
Isastrea haldonensis, *Dunc.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Hl.
„ sp.	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
Leptocyathus gracilis, *Dunc.*	–	–	–	–	–	–	–	–	–	–	–	–	g	–	g F.
Micrabacia coronula, *Goldf.*	–	–	–	–	–	–	–	7	–	–	10	†	–	–	7 H. 10 War. Dor.
Onchotrochus Carteri, *Dunc.*	–	–	–	–	–	–	–	–	–	–	10	†	–	–	10 N.D.
Oroseris haldonensis, *Dunc.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Hl.
Parasmilia, new sp.	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
Peplosmilia Austeni, *Dunc.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Hl. Bl.
Placosmilia cuneiformis, *E. & H.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Hl.
„ depressa, *E. & H.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Hl.
„ magnifica, *Dunc.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Hl.
„ Parkinsoni, *E. & H.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Hl.
„ tuberosa, *M. E.*	–	–	–	–	4	5	–	–	–	–	–	–	–	–	4 Dev. 5 Bl.
Rhizangia elongata, *Dunc.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	(= Podoseris, *Dunc.*) 7 H.
„ mammilliformis, *Dunc.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 H.
Smilotrochus (*see* Ceratotrochus and Trochocyathus).															
Stelloria incrustans, *Dunc.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Hl.
Stephanophyllia Bowerbanki, *M. E.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War.
Thamnastrea Belgica, *E. & H.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Hl.
„ Ramsayi, *Dunc.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Hl.
Trochocyathus angulatus, *Dunc.*	–	–	2	–	–	–	6	–	–	–	–	–	–	–	(Smilotrochus, Dunc.) 2 Cam. Bd.
„ calcaratus, *Tomes*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ conulus, *Phil.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	(=Smilotrochus elongatus, Dunc.) 2 F. 3 F. E.
„ harveyanus, *E.&H.*	–	–	2	3	–	–	6	–	–	–	–	–	–	–	(Smilotrochus) 2 F. R. Bd. 3 F.
„ ? Kœnigi, *Mant.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F. Ring. Blet.
„ Wiltshirei, *Dunc.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
Trochosmilia sulcata, *E. & H.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ varians, *Dunc.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Hl.
Trochoseris constricta, *Dunc.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Hl.
„ Morrisii, *Dunc.*	–	–	–	–	–	5	–	–	–	–	–	–	–	–	5 Hl.

SPECIES.	* Found also in Lower Cretaceous.	Lower Gault. 1 Mammillatus Zone.	Lower Gault. 2 Lower Gault Clays.	Zone of Amm. rostratus. 3 Upper Gault.	Zone of Amm. rostratus. 4 Malmstone and Sands.	Zone of Amm. rostratus. 5 Blackdown and Haldon.	6 Cambridge Greensand.	7 Red Chalk.	Zone of Pecten asper. 8 Lower Beds.	Zone of Pecten asper. 9 Chert Beds.	Zone of Pecten asper. 10 Highest Beds.	† Range into Chalk.	g Gault.	s Upper Greensand.	Localities and Remarks.
ACTINOZOA—cont.															
HYDROZOA.															
Parkeria compressa, *Carter*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
„ sphærica, *Carter*	–	–	–	–	–	5	6	–	–	–	10	–	–	–	5 Hl. 10 N. Dor.
SPONGIDA.															
Calcareous Sponges.															
Corynella rugosa, *Hinde*	–	–	–	–	–	–	–	–	–	9	–	–	–	–	Wilts. (horizon uncertain).
„ socialis, *Hinde*	–	–	–	–	–	–	–	–	–	9	–	–	–	–	Wilts. (horizon uncertain).
Elasmostoma consobrinum, *d'Orb.*	–	–	–	–	–	–	–	–	–	9	10	–	–	–	10 M.B. War.
„ normannianum, *d'Orb.*	–	–	–	–	–	–	–	–	–	–	?	–	–	–	? 10 War.
Pachytilodia infundibuliformis, *Goldf.*	–	–	–	–	–	–	–	–	–	?	–	–	–	–	Wilts. (horizon uncertain).
Peronella furcata, *Goldf.*	–	–	–	–	–	–	–	–	–	?	–	–	–	–	Wilts. (horizon uncertain).
Pharetrospongia Strahani, *Sollas*	–	–	–	–	–	–	–	–	–	?	–	–	–	–	Wilts. (horizon uncertain).
Porosphæra urceolata, *Phil.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War.
„ sp.															
Trematocystia Orbignyi, *Hinde*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War. MB.
„ siphonioides, *Mich.*	–	–	–	–	–	–	–	–	–	–	10	–	–	–	10 War.
Siliceous Sponges.															
Axinella stylus, *Hinde*	–	–	–	–	–	–	–	–	–	9	–	–	–	–	9 IW.
Carterella cylindrica, *Zitt.*	–	–	–	–	–	–	–	–	–	9	–	–	–	–	9 War.
Chenendopora Michelini, *Hinde*	–	–	–	–	–	–	–	–	–	9	–	–	–	–	9
Cephalites Benettiæ, *Mant.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
„ capitatus, *T. Smith*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
„ compressus, *T. Sm.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
„ longitudinalis, *T. Sm.*	–	–	–	3 ?	–	–	6	–	–	–	–	–	–	–	[=C. guttatus, T. Sm.]
Doryderma Benetti, *Hinde*	–	–	–	–	–	–	–	–	–	9	–	–	–	–	9 War.
„ dichotomum, *Benett*	–	–	–	–	–	–	–	–	–	9	–	–	–	–	9 War.
Eubrochus clausus, *Sollas*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
Hallirhoa agariciformis, *Benett*	–	–	–	–	–	–	–	–	–	9	10	–	–	–	9 War. 10 IW.
„ costata, *Lam.*	–	–	–	–	–	–	–	–	–	9	–	–	–	–	9 War.
Heterostinia obliqua, *Benett*	–	–	–	–	–	–	–	–	–	–	–	–	–	s	s IW.
Holodictyon capitatum, *Hinde*	–	–	–	–	–	–	–	–	–	9	–	–	–	–	9 War.
Jerea Websteri, *Sow.*	–	–	–	–	4	–	–	–	–	9	–	–	–	–	4 De IW. 9 War.
„ reticulata, *Hinde*	–	–	–	–	–	5	–	–	–	9	–	–	–	–	5 Bl. 9 War.
Jereica cylindrica, *Hinde*	–	–	–	–	–	–	–	–	–	9	–	–	–	–	9 War.
Kalpinella pateriformis, *Hinde*	–	–	–	–	–	–	–	–	–	9	–	–	–	–	9 War.
„ rugosa, *Hinde*	–	–	–	–	–	–	–	–	–	9	–	–	–	–	9 War.
Nematinion calyculum, *Hinde*	–	–	–	–	–	–	–	–	–	9	–	–	–	–	9 War.

SPECIES.		Lower Gault.		Zone of Amm. rostratus.					Zone of Pecten asper.						LOCALITIES AND REMARKS.
	* Found also in Lower Cretaceons.	Mammillatus Zone. 1	Lower Gault Clays. 2	Upper Gault. 3	Malmstone and Sands. 4	Blackdown and Haldon. 5	Cambridge Greensand. 6	Red Chalk. 7	Lower Beds. 8	Chert Beds. 9	Highest Beds. 10	Range into Chalk. †	Gault. g	Upper Greensand. s	
SPONGIDA—cont.															
Siliceous Sponges—cont.															
Ophrystoma ocellatum, *Seeley* -	–	–	–	–	–	–	6	–	–	–	–	–	–	–	(Porospongia) = Ventriculites cavatus, Sollas.
Pachypoterion compactum, *Hinde*	–	–	–	–	–	–	–	–	–	9	–	–	–	–	9 War.
" robustum, *Hinde*	–	–	–	–	–	–	–	–	–	9	–	–	–	–	9 War. Pewsey.
Phymatella nodosa, *Hinde*	–	–	–	–	–	–	–	–	–	9	–	–	–	–	9 War.
Plocoscyphia labrosa, *T. Sm.* -	–	–	–	–	–	–	–	–	–	9	–	–	–	–	9 IW. (?)
Polyjerea arbuscula, *Hinde* -	–	–	–	–	–	–	–	–	–	9	–	–	–	–	9 War.
" lobata, *Hinde* -	–	–	–	–	–	–	–	–	–	9	–	–	–	–	9 War.
Rhopalospongia gregaria, *Benett*	–	–	–	–	–	–	–	–	–	9	–	–	–	–	9 War.
" obliqua, *Hinde*	–	–	–	–	–	–	–	–	–	9	–	–	–	–	9 War.
Sclerokalia Cunningtoni, *Hinde*	–	–	–	–	–	–	–	–	–	–	–	–	–	s	s Wilts.
Siphonia tulipa, *Zitt.* -	–	–	–	3	4	5	–	–	–	9	10	–	–	–	3 F. 4 De. IW. 5 Bl. 9 War. IW. 10 N.D.
Trachysycon nodosum, *Hinde*	–	–	–	–	–	–	–	–	–	9	–	–	–	–	9 War.
Ventriculites mammillaris, *Smith*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
" ? quincuncialis, ? *Sm.*	–	–	–	–	–	–	6	7	–	–	–	–	–	–	7 Hun. Sp.
" ? texturatus, ? *Goldf.*	–	–	–	3	–	–	6	7	–	–	–	–	–	–	[=tesselatus], 3 Bu. 7 Hun.
FORAMINIFERA.															
Ammodiscus gordialis, *J. & P.*			2	3	–	–	–	7	–	–	–	†	–	–	(=Planorbulina.) 2 F. De. He. Nor. 3 F. 7 Sp.
" incertus, *d'Orb.* -	*	–	2	3	–	–	–	7	–	–	–	†	–	–	2 F. Bu. He. Nor. 3 F. 7 Sp.
" millettianus, *Chapm.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
" pusillus, *Gein.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 Go.
" tenuis, *Brady*	–	–	2	3	–	–	–	7	–	–	–	†	–	–	
Anomalina ammonoides, *Reuss* -	*	–	2	3	–	–	6	7	–	–	–	†	–	–	2 F. Bu. He. BV. Go. 3 F. 7 Hun. Sp.
" clementiana, *d'Orb.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
" complanata, *Reuss* -	*	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. BV. Go. 3 F.
" grosserugosa, *Gümb.*	–	–	–	–	–	–	6	7	–	–	–	–	–	–	7 Hun. Sp.
rudis, *Reuss* - -	–	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. He. Go. 3 F.
Biloculina undulata, *Chapm.*															
Bolivina textilarioides, *Reuss* -	*	–	2	3	–	–	–	7	–	–	–	†	–	–	2 F. 3 F. 7 Sp.
" Beyrichi, Rss. var. alata	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Sp.
Bulimina affinis, *d'Orb.* - -	*	–	2	3	–	–	–	7	–	–	–	†	–	–	2 F. Ds. Bu. 3 F. 7 Sp.
" brevis, *d'Orb.* -	*	–	2	3	–	–	–	–	–	–	–	†	–	–	2 Nor. 3 F.
" elegans, *d'Orb.* - -	–	–	–	–	–	–	6	–	–	–	–	†	–	–	
" murchisoniana, *d'Orb.*	*		–	3		–	6	–	–	–	–	†	–	–	3 F.
" obtusa, *d'Orb.* - -	*	–	–	3	–	–	6	–	–	–	–	†	–	–	3 F. Bu Nor.
" obliqua, *d'Orb.*	–	–	2	3	–	–	6	–	–	–	–	†	–	–	2 De. 3 F.
" Orbignyi, *Reuss*	–	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. Nor. 3 F.
" Presli, *Reuss*		–	2	3	–		–	7	–	–	–	†	–	–	2 F. Ed. He. Nor. 3 F. 7 Hun. Sp.
" " var. sabulosa *Chapm.*		–	–	3	–	–	–	–	–	–	–	†	–	–	3 F.
" pyrula, *d'Orb.* -		–	2	3	–	–		–	–	–	–	†	–	–	2 Nor. 3 F.

SPECIES.	Found also in Lower Cretaceous.	Lower Gault. Mammillatus Zone.	Lower Gault. Lower Gault Clays.	Zone of Amm. rostratus. Upper Gault.	Zone of Amm. rostratus. Malmstone and Sands.	Zone of Amm. rostratus. Blackdown and Haldon.	Cambridge Greensand.	Red Chalk.	Zone of Pecten asper. Lower Beds.	Zone of Pecten asper. Chert Beds.	Zone of Pecten asper. Highest Beds.	Range into Chalk.	Gault.	Upper Greensand.	LOCALITIES AND REMARKS.
	*	1	2	3	4	5	6	7	8	9	10	†	g	s	
FORAMINIFERA—cont.															
Cristellaria bononiensis, *Berth.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ bradyana, *Chapm.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ Bronni, *Roemer*	–	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F., BV.
„ complanata, *Reuss*	–	–	–	3	–	–	–	7	–	–	–	–	–	–	3 F. 7 Hun. Li.
„ convergens, *Born.*	*	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. 3 F.
„ circumcidansa, *Berth.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. BV.
„ costulata, *Chapm.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ cultrata, *Montf.*	–	–	–	–	–	–	–	7	–	–	–	†	–	–	7 Sp.
„ crepidula, *F. & M.*	*	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ cymboides, *d'Orb.*	*	–	–	3	–	–	–	7	–	–	–	†	–	–	3 F. 7 Sp.
„ diademata, *Berth.*	–	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. 3 F.
„ exilis, *Reuss*	*	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. 3 F.
„ „ var. crispata, *Chap.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ gaultina, *Berth.*	–	–	2	3	–	–	6	–	–	–	–	–	–	–	2 F. BV. Go. Bu. He. 3 F.
„ gibba, *d'Orb.*	–	–	2	3	–	–	–	7	–	–	–	†	–	–	2 F. BV. Go. He. 7 Sp.
„ gladius, *Philippi.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ humilis, *Reuss*	*	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ italica, *Defr.*	*	–	2	3	–	–	–	7	–	–	–	†	–	–	2 F. 3 F. 7 Hun. Sp.
„ latifrons, *Brady*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	—
„ linearis, *Reuss*	*	–	2	3	–	–	–	–	–	–	–	–	–	–	2 BV. 3 F.
„ lata, *Reuss*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Sp.
„ lituola, *Reuss*	–	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. 3 F.
„ lobata, *Costa.*	*	–	–	3	–	–	–	–	–	–	–	†	–	–	3 F.
„ navicula, *d'Orb.*	–	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. 3 F.
„ Marcki, *Reuss*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Sp.
„ multisepta *Reuss*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Sp.
„ oligostegia, *Reuss*	*	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. 3 F.
„ parallela, *Reuss*	*	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ planiuscula, *Reuss*	*	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. 3 F.
„ rotulata, *Lam.*	–	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. BV. 3 F.
„ „ var. macrodiscus, *Reuss*	*	–	2	3	–	–	–	7	–	–	–	†	–	–	2 F. BV. Go. 3 F. 7 Hun. Li.
„ Schloenbachi, *Reuss*	*	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. BV. 3 F.
„ secans, *Reuss* var. angulosa, *Chapm.*	–	–	–	3	–	–	–	–	–	–	–	†	–	–	3 F.
„ scitula, *Berth.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ sternalis, *Berth.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ striata, *Chap.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ sulcifera, *Reuss*	*	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ subalata, *Reuss*	*	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. BV. Go. 3 F.
„ triangularis, *d'Orb.*	–	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. 3 F.
„ tripleura, *Reuss*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ trunculata, *Berth.*	–	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. 3 F.
„ turgidula, *Reuss*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. BV. 3 F.
„ variabilis, *Reuss*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Sp.
„ vestita, *Berth.*	*	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. Bu. He. 3 F.
Discorbina globularis *d'Orb.*	–	–	–	3	–	–	–	–	–	–	–	†	–	–	3 F.
„ orbicularis, *Terq.*	*	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ pileolus, *d'Orb.*	*	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ rugosa, *d'Orb.*	*	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ turbo, *d'Orb.*	*	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ vilardeboana, *d'Orb.*	*	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
Flabellina didyma, *Berth.*	–	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. 3 F.
Frondicularia Archiaciana, *d'Orb.*	–	–	2	–	–	–	–	7	–	–	–	†	–	–	2 F. 7 loc?
„ biformis, *Marsson.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Sp.
„ bicornis, *Reuss*	–	–	–	–	–	–	6	–	–	–	–	†	–	–	
„ Cordai, *Reuss.*	–	–	2	3	–	–	6	–	–	–	–	–	–	–	2 F. 3 F.
„ denticulo-carinata *Chap.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ Fritschi, *Perner*	–	–	2	3	–	–	6	–	–	–	–	†	–	–	2 He. 3 F.

SPECIES.	Found also in Lower Cretaceous.	Lower Gault: Mammillatus Zone.	Lower Gault: Lower Gault Clays.	Zone of Amm. rostratus: Upper Gault.	Zone of Amm. rostratus: Malmstone and Sands.	Zone of Amm. rostratus: Blackdown and Haldon.	Cambridge Greensand.	Red Chalk.	Zone of Pecten asper: Lower Beds.	Zone of Pecten asper: Chert Beds.	Zone of Pecten asper: Highest Beds.	Range into Chalk.	Gault.	Upper Greensand	LOCALITIES AND REMARK
	*	1	2	3	4	5	6	7	8	9	10	†	g	s	
FORAMINIFERA—cont.															
Frondicularia gaultina, *Reuss*		–	2	3	–		–	7	–	–	–	–	–	–	2 F. 3 F. 7 Sp.
„ guestphalica, *Rss.*	–		–	3	–		–	–	–	–	–	–	–	–	3 F.
„ inversa, *Reuss*	–	–	–	3	–		–	–	–	–	–	†	–	–	3 F.
„ Karreri, *Berth.*	–	–	2	3	–		–	–	–	–	–	–	–	–	2 F. 3 F.
„ lanceola, *Reuss*	–	–	–	3	–	–	–	–	–	–	–	†	–	–	3 F.
„ Loryi, *Berth.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ microdiscus, *Reuss*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ Parkeri, *Reuss*	–	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. 3 F.
„ planifolia, *Chapm.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ perovata, *Chapm.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ quadrata, *Chap.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ atrigillata, *Reuss*	–	–	2	3	–	–	–	–	–	–	–	?	–	–	2 F. Go. He. 3 F.
„ Ungeri, *Reuss*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	
Gaudryina dispansa, *Chapm.*	–	–	2	3	–	–	–	–	–	–	–	†	–	–	2 BV. 3 F.
„ filiformis, *Berth.*	*	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. 3 F.
„ oxycona, *Reuss*	–	–	2	3	–	–	–	–	–	–	–	†	–	–	2 He. 3 F.
„ pupoides, *d'Orb.*	*	–	2	3	–	–	6	7	–	–	–	†	–	–	2 F. Bn. 3 F. 7 Sp.
„ rugosa, *d'Orb.*	–	–	–	3	–	–	–	–	–	–	–	†	–	–	3 F.
Globigerina æquilateralis, *Brady*	–	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. 3 F
„ bulloidea, *d'Orb.*	*	–	2	3	–	–	6	7	–	–	–	†	–	–	2 F. 3 F. 7 Hun. Sp.
„ cretacea, *d'Orb.*	*	–	2	3	–	–	6	7	–	–	–	†	–	–	2 F. Bu. Ha. 3 F. 7 Hun Sp. Li. Yo.
„ linnæana, *d'Orb.*	–	–	–	–	–	–	–	7	–		–	†	–	–	7 Hun. Sp.
Haplostiche Sherborni, *Chapm.*	–	–	–	3	–	–	–	–	–	–	–	†	–	–	3 F.
Haplophragmium acutidorsatum. *Hantk.*	*	–	2	3	–	–	–	–	–	–	–	†	–	–	2 passim. 3 F.
„ æquale *Roemer*	*	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. BV. Go. De. 3 F.
„ agglutinans, *d'Orb.*	–	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. 3 F.
„ elegans, *Chap.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ emaciatum, *Brady*	–	–	2	–	–	–	–	–	–	–	–	†	–	–	2 BV.
„ glomeratum, *Brady*	–	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. 3 F.
„ globigeriniforme, *P. & S.*	–	–	2	3	–	–	6	–	–	–	–	–	–	–	2 F. 3 F.
„ irregulare, *Roem.*	–	–	–	–	–	–	6	–	–	–	–	†	–	–	
„ latidorsatum, *Born.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. De. 3 F.
„ „ var.												–	–	–	3 F. De.
„ papillosum, *Chap.*	–	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. De. 3 F.
„ nanum, *Brady*	–	–	2	3	–	–	–	–	–	–	–	†	–	–	2 passim. 3 F.
„ nonioninoidea, *Rss.*	*	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ Terquemi, *Berth.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F.
Hormosina globulifera, *Brady*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	
Lagena acuticosta, *Reuss*	*	–	2	–	–	–	–	–	–	–	–	†	–	–	2 F.
„ alifera, *Reuss*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ apiculata, *Reuss*	–	–	2	3	–	–	–	7	–	–	–	†	–	–	2 F. 3 F. 7 Hun. Sp. Li.
„ „ var. emaciata, *Reuss*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Sp.
„ aspera, *Reuss*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ cincta, *Seg.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Sp.
„ globosa, *Mont.*	–	–	–	3	–	–	–	7	–	–	–	†	–	–	3 F. 7 Sp.
„ gracilis, *Williamson*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ gracillima. *Seg.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ hispida, *Reuss*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ lævia, *Mont.*	–	–	2	3	–	–	–	7	–	–	–	–	–	–	2 F. 3 F. 7 Hun. Sp.
„ marginata, *W. & Boys*	–	–	–	3	–	–	6	–	–	–	–	–	–	–	3 F.
„ quinquelatera, *Brady*												–	–	–	2 F.
var. inflata, *Chapm.*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ striato-punctata, *P. & J.*	–	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F.
„ sulcata, *Walk. & Jacob*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	

SPECIES.		Lower Gault.		Zone of Amm. rostratus.					Zone of Pecten asper.						LOCALITIES AND REMARKS.
	Found also in Lower Cretaceous.	Mammillatus Zone.	Lower Gault Clays.	Upper Gault.	Malmstone and Sands.	Blackdown and Haldon.	Cambridge Greensand.	Red Chalk.	Lower Beds.	Chert Beds.	Highest Beds.	Range into Chalk	Gault.	Upper Greensand.	
	*	1	2	3	4	5	6	7	8	9	10	†	g	s	
FORAMINIFERA—cont.															
Lingulina nodosaria, *Reuss*	*	—	2	—	—	—	—	7	—	—	—	—	—	—	(=carinata, Rss.) 2 F. 7 Sp.
" semiornata, *Reuss*	*	—	2	3	—	—	—	—	—	—	—	†	—	—	2 F. He. 3 F.
Marginulina æquivoca, *Reuss*	*	—	2	3	—	—	—	—	—	—	—	†	—	—	2 F. BV. Go. 3 F.
" asperula, *Chapm.*	—	—	—	3	—	—	—	—	—	—	—	—	—	—	3 F.
" debilis, *Berth.*	*	—	2	3	—	—	—	—	—	—	—	†	—	—	2 F. 3 F.
" folkstoniensis, *Chap*	—	—	2	3	—	—	—	—	—	—	—	—	—	—	2 F. 3 F.
" glabra, *d'Orb.*	—	—	—	3	—	—	—	7	—	—	—	†	—	—	3 F. 7 Sp.
" hamulus, *Chapm.*	—	—	2	3	—	—	—	—	—	—	—	—	—	—	2 F. 3 F.
" inæqualis, *Reuss*	—	—	2	3	—	—	—	7	—	—	—	†	—	—	2 F. 3 F. 7 Sp.
" Jonesi, *Reuss*	*	—	2	3	—	—	—	—	—	—	—	†	—	—	2 F. Go. He. 3 F.
" linearis, *Reuss*	*	—	2	3	—	—	—	—	—	—	—	—	—	—	2 F. 3 F.
" Munieri, *Berth.*	*	—	2	3	—	—	—	—	—	—	—	†	—	—	2 F. 3 F.
" Parkeri, *Reuss*	*	—	2	—	—	—	—	—	—	—	—	—	—	—	2 F.
" robusta, *Reuss*	*	—	2	3	—	—	—	—	—	—	—	†	—	—	2 F. 3 F.
" striatocostata, *Reuss*	—	—	2	3	—	—	—	—	—	—	—	—	—	—	2 F. 3 F.
" tenuissima, *Reuss*	—	—	—	3	—	—	—	—	—	—	—	—	—	—	—
" variabilis, *Neug.*	—	—	—	—	—	—	—	7	—	—	—	—	—	—	7 Sp.
Miliolina agglutinans, *d'Orb.*	—	—	—	3	—	—	—	—	—	—	—	—	—	—	3 F.
" Ferussaci, *d'Orb.*	—	—	2	3	—	—	—	—	—	—	—	—	—	—	2 Bu., He. 3 F.
" tricarinata, *d'Orb.*	—	—	2	3	—	—	—	—	—	—	—	—	—	—	2 He. 3 F.
" venusta, *Karrer*	—	—	2	3	—	—	—	—	—	—	—	†	—	—	2 K. Bn. He. 3 F.
Nodosaria abnormis, *Reuss*	—	—	2	—	—	—	—	7	—	—	—	—	—	—	2 F. 7 Sp.
" bambusa, *Chapm.*	—	—	2	3	—	—	—	—	—	—	—	—	—	—	2 F. 3 F.
" brevis, *d'Orb.*	—	—	—	—	—	—	—	7	—	—	—	—	—	—	7 Sp.
" (G) candela, *Egger*	—	—	—	—	—	—	—	7	—	—	—	—	—	—	7 Sp.
" calomorpha, *Reuss*	—	—	—	—	—	—	—	7	—	—	—	—	—	—	7 Hun.
" (D) communis, *d'Orb.*	—	—	2	3	—	—	6	7	—	—	—	†	—	—	2 F. 3 F. 7 Hun. Sp.
" (D) consobrina, *d'Orb.*	—	—	2	3	—	—	—	—	—	—	—	†	—	—	2 F. 3 F.
" (D) costellata, *Reuss*	—	—	—	3	—	—	—	—	—	—	—	†	—	—	3 F.
" (G) cylindracea, *Reuss*	—	—	—	3	—	—	—	7	—	—	—	†	—	—	3 F. 7 Sp.
" (D) cylindroides, *Reuss*	—	—	2	3	—	—	—	—	—	—	—	†	—	—	2 F. 3 F.
" (D) expansa, *Reuss*	—	—	2	3	—	—	—	—	—	—	—	†	—	—	2 F. 3 F.
" (D) farcimen, *Reuss*	—	—	—	3	—	—	—	—	—	—	—	†	—	—	3 F.
" (D) filiformis, *d'Orb.*	—	—	—	—	—	—	—	7	—	—	—	†	—	—	7 Sp.
" (D) Fontannesi, *Berth*	—	—	2	3	—	—	—	—	—	—	—	†	—	—	2 F. Go. 3 F.
" (D) gracilis *d'Orb.*	—	—	2	3	—	—	—	—	—	—	—	†	—	—	2 F. 3 F.
" (D) hamulifera, *Reuss*	*	—	—	3	—	—	—	—	—	—	—	—	—	—	3 F.
" hispida, *d'Orb.*	—	—	2	3	—	—	—	—	—	—	—	—	—	—	2 F. 3 F.
" (G) humilis, *Rœmer*	—	—	2	3	—	—	—	—	—	—	—	†	—	—	2 F. He. 3 F.
" inflata, *Reuss*	—	—	2	3	—	—	—	—	—	—	—	†	—	—	2 F. 3 F.
" (D) intercellularis *Brady*	—	—	2	3	—	—	—	—	—	—	—	—	—	—	2 F. 3 F.
" internotata, *Chapm.*	—	—	2	3	—	—	—	—	—	—	—	—	—	—	2 F. 3 F.
" (G) lævigata, *d'Orb.*	—	—	—	—	—	—	—	7	—	—	—	—	—	—	7 Sp.
" (D) legumen, *Reuss*	—	—	2	3	—	—	—	—	—	—	—	†	—	—	2 F. 3 F.
" limbata, *d'Orb.*	—	—	—	—	—	—	—	7	—	—	—	—	—	—	7 Hun.
" longiscata, *d'Orb.*	—	—	—	—	—	—	—	7	—	—	—	—	—	—	7 Sp.
" (D) Lorneiana, *d'Orb.*	—	—	2	3	—	—	—	—	—	—	—	†	—	—	2 F. Ho. 3 F.
" (G) marginulinoides, *Rss.*	—	—	—	—	—	—	—	7	—	—	—	—	—	—	7 Sp.
" (D) mucronata, *Neug.*	—	—	2	3	—	—	—	7	—	—	—	—	—	—	2 F. 3 F. 7 Sp.
" (G) mutabilis, *Reuss*	*	—	2	3	—	—	—	—	—	—	—	†	—	—	2 F. He. 3 F.
" obtusissima, *Reuss*	—	—	—	—	—	—	—	7	—	—	—	—	—	—	7 Sp.
" (D) obscura, *Reuss*	*	—	2	3	—	—		7	—	—	—	†	—	—	2 F. 3 F. 7 Sp.
" oligostega, *Reuss*	—	—	2	3	—	—	—	7	—	—	—	†	—	—	2 F. 3 F. 7 Sp.
" orthopleura, *Reuss*	—	—	2	3	—	—	—	—	—	—	—	†	—	—	2 F. He. 3 F.
" (D) pauperata, *d'Orb.*	—	—	2	3	—	—	—	—	—	—	—	—	—	—	2 F. 3 F.
" (D) paupercula, *Reuss*	—	—	2	3	—	—	—	—	—	—		†	—	—	2 F. BV. Go. 3 F.
" perpusilla, *Chapm.*	—	—	2	3	—	—	—	—	—	—		†	—	—	2 F. 3 F.
" prismatica, *Reuss*	*	—	2	3	—	—	—	7	—	—	—	†	—	—	2 F. 3 F. 7 Sp.
" (D) raristriata, *Chapm.*	—	—	2	3	—	—	—	—	—	—	—	†	—	—	2 He. 3 F.

NOTE.—Under *Nodosaria* the capital letters indicate *Dentalina* (D) and *Glandulina* (G).

SPECIES.	* Found also in Lower Cretaceous.	Lower Gault. Mammillatus Zone.	Lower Gault. Lower Gault Clays.	Zone of Amm. rostratus. Upper Gault.	Zone of Amm. rostratus. Malmstone and Sands.	Zone of Amm. rostratus. Blackdown and Haldon.	Cambridge Greensand.	Red Chalk.	Zone of Pecten Asper. Lower Beds.	Zone of Pecten Asper. Chert Beds.	Zone of Pecten Asper. Highest Beds.	Range in Chalk.	Gault.	Upper Greensand.	LOCALITIES AND REMARKS.
	*	1	2	3	4	5	6	7	8	9	10	†	g	s	
FORAMINIFERA—cont.															
„ raphanus, *Lin.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
„ radicula, *L.* var. Jonesi, *Reuss*	–	–	–	3	–	–	–	7	–	–	–	–	–	–	3 F. 7 Hun. Li.
„ (D) Roemeri, *Neug.*	*	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ sceptrum, *Reuss*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ soluta, *Reuss*	–	–	2	3	–	–	–	7	–	–	–	†	–	–	2 F. 3 F. 7 Sp.
„ „ var. discrepans, *Reuss*	–	–	–	3	–	–	–	–	–	–	–	†	–	–	3 F.
„ „ var. pulchella, *Chap.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ (D) tenuicosta, *Reuss*	*	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. BV. Go. He. 3 F
„ tetragona, *Reuss*	*	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ (D) tubifera, *Reuss*	*	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ (D) xiphioides, *Reuss*	*	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ (D) Zippei, *Reuss*	–	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. 3 F.
Nubecularia depressa, *Chap.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ nodulosa, *Chap.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. He. 3 F.
Orbulina universa, *d'Orb.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Sp. Li.
Patellina concava, *P. & J.*	–	–	–	–	–	–	–	–	–	9	–	–	–	–	9 Dev. Hl.
Placopsilina cenomana, *d'Orb.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ vesicularis, *Brady*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
Pleurostomella alternans, *Schwa.*	–	–	2	3	–	–	–	7	–	–	–	†	–	–	2 F. He. 3 F. 7 Sp.
„ obtusa, *Berth.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. He. 3 F.
„ subnodosa, *Reuss.*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Sp.
Polymorphina augusta, *Egger*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ communis, *d'Orb.*	–	–	–	3	–	–	–	–	–	–	–	†	–	–	3 F.
„ compressa, *d'Orb.*	–	–	–	3	–	–	–	7	–	–	–	–	–	–	3 F. 7 Sp.
„ fusiformis, *Roemer*	–	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. 3 F.
„ „ var. horrida, *Reuss.*	–	–	2	3	–	–	–	7	–	–	–	–	–	–	2 F. 3 F. 7 Sp.
„ gibba, *d'Orb.*	–	–	2	3	–	–	–	7	–	–	–	†	–	–	2 He. 3 F. 7 Sp.
„ „ var. acuplacenta, *J. & Ch.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ gutta, *d'Orb.*	*	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ „ var. diffusa, *J. & Ch.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ lactea, *W. & J.*	–	–	–	3	–	–	–	7	–	–	–	†	–	–	3 F. 7 Sp.
„ „ var. acuplacenta, *J. & Ch.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ sororia, *Reuss*	–	–	2	3	–	–	–	7	–	–	–	†	–	–	2 F. 3 F.
„ „ var. acuplacenta, *J. & Ch.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ „ var. cuspidata, *Brady.*	–	–	2	3	–	–	–	–	–	–	–	–	–	.	2 F. 3 F.
Polystomella macella, *F. & M.*	–	–	–	–	–	–	–	7	–	–	–	–	–		7 Sp.
Pulvinulina caracolla, *Roem.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ Carpenteri, *Reuss*	–	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. 3 F.
„ elegans, *d'Orb.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. G. 3 F.
„ Haueri, *d'Orb.*	–	–	2	–	–	–	–	–	–	–	–	–	..	..	2 F.
„ Menardi, *d'Orb.*	–	–	–	–	–	–	–	7	–	–	–	–	.		7 Sp.
„ reticulata, *Reuss*	–	–	2	3	–	–	–	–	–	–	–	–	–	..	2 F. BV 3 F.
„ spinulifera, *Reuss*	–	–	2	3	–	–	–	–	–	–	–	–			2 F. Ha 3 F.
Ramulina aculeata, *Wright*	–	–	2	3	–	–	–	7	–	–	–	†	..	–	2 F. Bu. Ha. 3 F. 7 Sp.
„ cervicornis, *Chapm.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ globulifera, *Brady.*	–	–	2	3	–	–	–	–	–	–	–	†	.	–	2 F. 3 F.
„ laevia, *Jones*	–	–	–	3	–	–	–	–	–	–	–	–	..	–	3 F.

SPECIES.	* Found also in Lower Cretaceous.	Lower Gault. 1 Mammillatus Zone.	Lower Gault. 2 Lower Gault Clays.	Zone of Amm. rostratus. 3 Upper Gault.	Zone of Amm. rostratus. 4 Malmstone and Sands.	Zone of Amm. rostratus. 5 Blackdown and Haldon.	6 Cambridge Greensand.	7 Red Chalk	Zone of Pecten asper. 8 Lower Beds.	Zone of Pecten asper. 9 Chert Beds.	Zone of Pecten asper. 10 Highest Beds.	† Range into Chalk.	g Gault.	s Upper Greensand.	LOCALITIES AND REMARKS.
FORAMINIFERA—cont.															
Reophax ampullacea, *Brady*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ cylindracea, *Chapm.*	–	–	–	3	–	–	–	–	–	–	–	†	–	–	3 F.
„ folkstoniensis, *Chapm.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ fusiformis, *Will.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ lageniformis, *Chapm.*	–	–	–	3	–	–	–	–	–	–	–	†	–	–	3 F.
„ scorpiurus, *Mont.*	–	–	–	3	–	–	–	–	–	–	–	†	–	–	3 F.
Rhabdogonium excavatum, *Reuss*	–	–	2	3	–	–	–	7	–	–	–	†	–	–	(= minutum, Rss.) 2 He. 3 F. 7 Sp.
„ maertense, *Reuss*	*	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ tricarinatum, *Orb.* var. acutangulum, *Reuss*	*	–	–	3	–	–	–	7	–	–	–	†	–	–	3 F. 7 Sp.
Rhizammina indivisa, *Brady*	–	–	–	3	–	–	–	–	–	–	–	†	–	–	3 F.
Rotalia Soldanii, *d'Orb.*, var. nitida, *Reuss*	–	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. He. 3 F.
Sagraina asperula, *Chapman*	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
„ calcarata, *Berth.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
Sphæroidina bulloides, *d'Orb.*	–	–	2	–	–	–	–	7	–	–	–	–	–	–	2 F. 7 Sp.
Spirillina tuberculata, *Brady*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
Spiroloculina asperula, *Karrer*	–	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. He. 3 F.
„ nitida, *d'Orb.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 He. 3 F.
„ papyracea, *B., S. & B.*	–	–	–	–	–	–	–	7	–	–	–	†	–	–	7 Sp.
„ tenuis, *Czjzek*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Sp.
Spiroplecta anceps, *Reuss*	–	–	–	3	–	–	–	–	–	–	–	†	–	–	3 F.
„ annectens, *P. & J.*	*	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. Nor. 3 F.
„ biformis, *P. & J.*	–	–	–	–	–	–	–	7	–	–	–	†	–	–	7 Sp.
„ complanata, *Reuss*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ prælonga, *Reuss*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
Textularia agglutinans, *d'Orb.*	–	–	–	3	–	–	6	7	–	–	–	†	–	–	3 F. 7 Sp.
„ attenuata, *Reuss*	–	–	–	–	–	–	–	7	–	–	–	–	–	–	7 Sp.
„ complanata, *Reuss*	–	–	2	3	–	–	–	7	–	–	–	†	–	–	2 F. He. 3 F. 7 Sp.
„ conica, *d'Orb.*	–	–	–	3	–	–	–	–	–	–	–	†	–	–	3 F.
„ fœda, *Reuss*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	3 F.
„ gramen, *d'Orb.*	*	–	2	3	–	–	–	7	–	–	–	†	–	–	2 He. 3 F. 7 Sp.
„ minuta, *Berth.*	*	–	2	3	–	–	–	7	–	–	–	†	–	–	(= pygmæa) 2 F. 3 F. 7 Hun. Sp.
„ parallela, *Reuss*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ prælonga, *Reuss*	*	–	–	3	–	–	–	7	–	–	–	†	–	–	3 F. 7 Sp.
„ sagittula, *Defr.*	*	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. 3 F.
„ trochus, *d'Orb.*	*	–	2	3	–	–	6	7	–	–	–	†	–	–	2 F. De. 3 F. 7 Hun. Sp.
„ turris, *d'Orb.*	*	–	2	–	–	–	6	7	–	–	–	†	–	–	2 F. He. 7 Hun. Sp.
Thurammina albicans, *Brady*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
Tritaxia pyramidata, *Reuss*	–	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. 3 F.
„ tricarinata, *Reuss*	*	–	2	3	–	–	–	–	–	–	–	†	–	–	(= Triloculina) 2 passim. 3 F.
Trochammina concava, *Chapm.*	–	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. BV. 3 F.
Truncatulina lobatula, *Walk.*	–	–	2	3	–	–	–	–	–	–	–	†	–	–	2 Bu. 3 F.
„ refulgens, *Montf.*	–	–	2	–	–	–	–	–	–	–	–	†	–	–	2 F.
„ variabilis, *d'Orb.*	–	–	–	–	–	–	–	7	–	–	–	†	–	–	7 Sp.
„ Wuellerstorfi, *Schwag.*	*	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
Vaginulina arguta, *Reuss.*	–	–	2	3	–	–	–	7	–	–	–	†	–	–	2 F. BV. 7 Sp.
„ Biochei, *Berth.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. He. 3 F.
„ comitina, *Bert.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
„ costulata, *Reuss.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	
„ discors, *F. Koch*	*	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
„ gaultina, *Berth.*	–	–	2	3	–	–	–	–	–	–	–	†	–	–	2 F. 3 F.
„ legumen, *Lin.*	–	–	–	–	–	–	–	7	–	–	–	†	–	–	7 Sp.
„ priceana, *Chapm.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.

SPECIES.	Found also in Lower Cretaceous.	Lower Gault. Mammillatus Zone.	Lower Gault. Lower Gault Clays.	Zone of Amm. rostratus. Upper Gault.	Zone of Amm. rostratus. Malmstone and Sands.	Zone of Amm. rostratus. Blackdown and Haldon.	Cambridge Greensand.	Red Chalk.	Zone of Pecten asper. Lower Beds.	Zone of Pecten asper. Chert Beds.	Zone of Pecten asper. Highest Beds.	Range into Chalk.	Gault.	Upper Greensand.	LOCALITIES AND REMARKS.
	*	1	2	3	4	5	6	7	8	9	10	†	g	s	
FORAMINIFERA—cont.															
Vaginulina recta, *Reuss*	–	–	2	3	–	–	–	7	–	–	–	†	–	–	2 F. He 3 F. 7 Sp
" " var. tenuistriata, *Chapm.*	–	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
" sparsicostata, *Reuss*	*	–	2	–	–	–	–	–	–	–	–	–	–	–	2 F.
" striolata, *Reuss*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3 F.
" strigillata, *Reuss*	–	–	2	3	–	–	–	–	–	–	–	†	–	–	2 Go. 3 F.
" truncata, *Reuss*	*	–	2	3	–	–	–	7	–	–	–	†	–	–	2 F. He. 3 F. 7 Sp.
" " var. robusta, *Berth. & Chapm.*	–	–	2	3	–		–	–	–	–	–	†	–	–	2 F. 3 F.
Valvulina conica, *P. & J.*	*	–	2	3	–	–		–	–	–	–	–	–	–	2 F. 3 F.
" fusca, *Will.*	*	–	2	3	–	–	–	–	–	–	–	–	–	–	2 F. 3 F.
Verneuillina parisiensis, *d'Orb.*	–	–	–	–	–	–	6	–	–	–	–	–	–	–	—
" propinqua, *Brady*	–	–	–	–	–	–	–	7	–	–	–	†	–	–	7 Sp.
" pygmæa, *Egger.*	–	–	2	3	–		–	–	–	–	–	–	–	–	2 F. 3 F.
" triquetra, *Munst.*	–	–	2	3	–	–	6	7	–	–	–	†	–	–	2 F. Ds. 3 F. 7 Sp.
" variabilis, *Brady*	–	–	2	3	–	–	–	–	–	–	–	†	–	–	2 Dev. 3 F.
Vitriwebbina lævis, *Sollas*	–	–	2	3	–	–	6	–	–	–	–	†	–	–	(Wsbbina) 2 F. Go 3 F.
" Sollasi, *Chapm.*	–	–	2	3	–	–	–	–	–	–	–	†	–	–	(Do.) 2 F. 3 F
" " var. gonoidea, *Chapm.*	–	–	–	3	–	–	–	–	–	–	–	–	–	–	(Do.) 3 F.
" tuberculata, *Sollas,*	–	–	2	–	–	–	6		–	–	–	†	–	–	(Do.) 2 F.

INDEX.

Names printed in italics are those of fossils which are figured, or to which special reference is made.

GEOLOGICAL SURVEY OF THE UNITED KINGDOM

HONI SOIT QUI MAL Y PENSE